THE IMPACT OF THE MAINTENANCE MANAGEMENT SYSTEM ON PRODUCTION OUTPUT AND PROFITABILITY AT THE PETROLEUM OIL AND GAS CORPORATION OF SOUTH AFRICA (PETROSA) GTL REFINERY

by

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ABSTRACT

The purpose of this study was to investigate the impact of the maintenance management system (MMS) on production output and profitability (PO&P) at the Petroleum Oil and Gas Corporation of South Africa (PetroSA) GTL Refinery as a source of competitive advantage. State-Owned Companies and, or more specifically the PetroSA GTL Refinery must maintain its strategic importance for government fuel security but, at the same time, it must compete against private refineries in terms of achieving high production volumes, maximising profitability and to maintain its stake of 6.5% of the available production capacity. The literature review for this study suggested that the maintenance management system (MMS) impacts positively on production output and profitability (PO&P). The MMS has a tremendous influence on PO&P at the PetroSA GTL Refinery. Using a quantitative research design, cross-sectional research survey and the Maintenance Scorecards (MS) assessment tool, this study was conducted on six areas of the PetroSA GTL Refinery. Two population groups, namely production and maintenance groups participated in the survey. Fifty-six respondents belonged to the maintenance group and thirty-eight respondents belonged to the Production Group. All the Maintenance and Production Group respondents completed the MS questions designed to fit the characteristics of these population groups. Correlation analysis in terms of the means, standard deviations, gap analysis, Pearson product moment correlation coefficient (r) as well as the coefficient of determination (R^2) was used to analyse the data. The findings of the study indicated a moderate positive linear correlation between the MMS and PO&P. Recommendations based on the findings were tabled in chapter 7 to improve and enhance production perspective (asset health gap), safety perspective (asset prioritisation gap) and the learning and growth perspective (skills and working condition gap).

LIST OF ABBREVIATIONS

AM	Asset Management
AGS	Air and Gas Separation
BS	Balanced Scorecard
BSI	Balanced Scorecard Institute
B&S	Blending and Storage
B/D	Barrels per day
CEF	Central Energy Fund
GTL&R	Gas to Liquid Refinery
KPI	Key Performance Indicator
MMS	Maintenance Management System
MMSI	Maintenance Management System Index
MS	Maintenance Scorecard
NOC	National Oil Company
O&U	Offsites and Utilities
PO	Production Output
PO&P	Production Output and Profitability
PAS 55	Publicly Available Standard (British Standard)
PM	Profit Maximisation
POI	Production Output Index
PO&PI	Production Output & Profitability Index
RBWS	Risk Based Work Selection
RCM	Reliability Centred Maintenance
REF	Refinery
RES	Reliability Engineering Services
RFM	Reforming
RMEG	Reliability and Maintenance Excellence Glossary
ROI	Return On Investment
SFF	Strategic Fuel Fund
SNT	Synthol
SOC	State Owned Company
TMEI	The Maintenance Excellence Institute

TOC	Theory Of Constraints
TPM	Total Productive Maintenance

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DEDICATION

This study is dedicated to:

- My Lord Jesus Christ, for the strength and ability to persist and finalise this project.
- My wife, Lerato who encouraged and supported me throughout the project. My children, Fihliwe, Lebo, Lesego, Samukele, and Mamello for love, support and respect.
- My late parents, Daniel and Ellen for their support and encouragement and
- My sisters Ntombi and Phindile for their encouragement.

DECLARATION OF OWN WORK

I, **Bafana Petrus Mahlangu**, declare that 'The Impact of the Maintenance Management System on Production Output and Profitability at the Petroleum Oil and Gas Corporation of South Africa (PetroSA) GTL Refinery' is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1: GENERAL OVERVIEW

The main sections of this chapter are depicted in Figure 1.1 below:

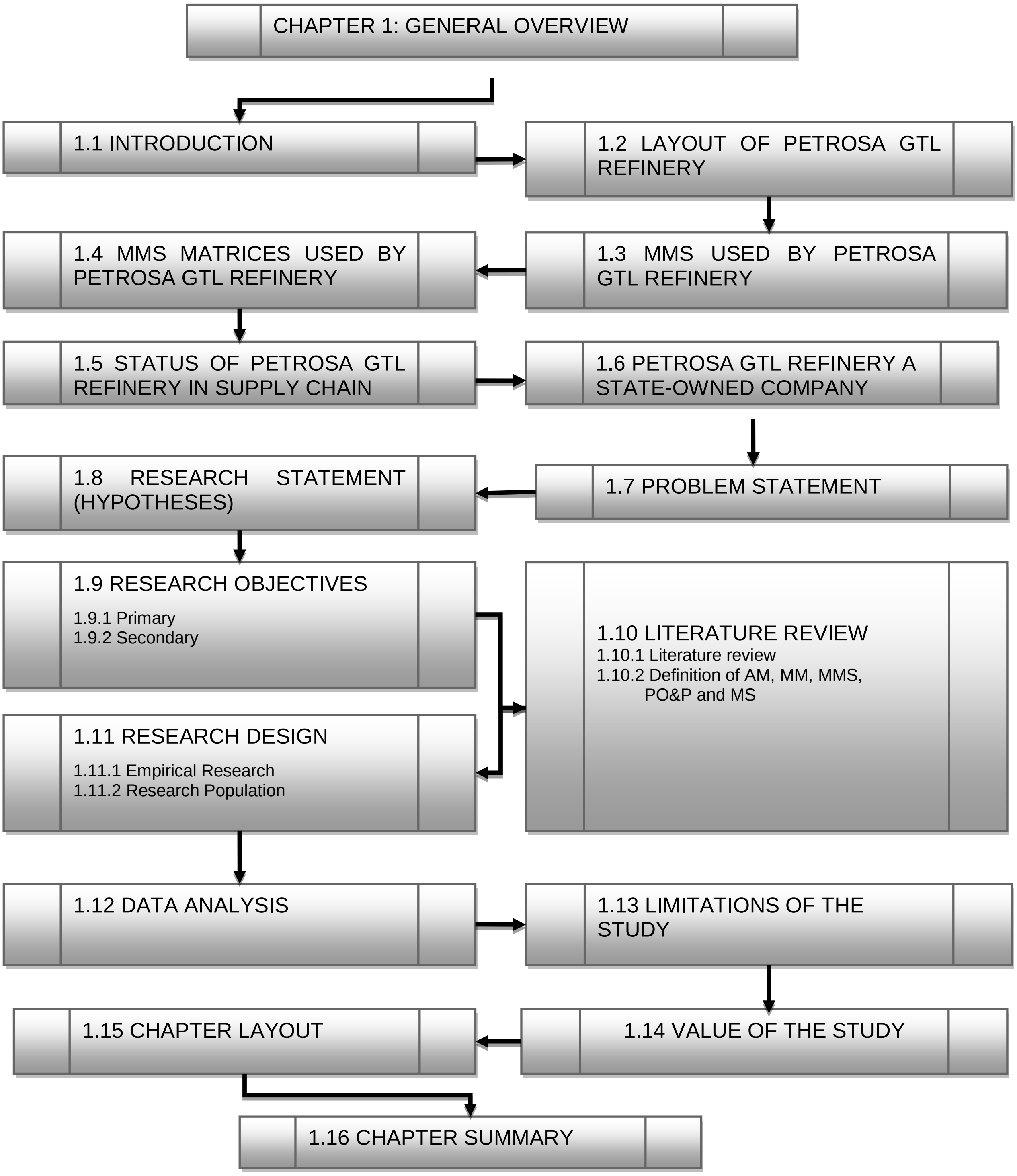

Figure 1.1 Layout of Chapter 1

1.1 INTRODUCTION

The proposed study focuses on the impact of the maintenance management system (MMS) on the Production Output (PO) and the profitability of the PetroSA GTL Refinery. The PetroSA GTL Refinery is situated in Mossel Bay in the Western Cape, South Africa. The study excludes the Head Office, depots (Bloemfontein and Tzaneen), FA Platform, Orca, Voorbaai and the Logistics Base divisions at PetroSA. PetroSA was formed in 2002 with the merger of Soekor E and P (Pty) Ltd, Mossgas (Pty) Ltd and parts of the strategic fuel fund (SFF).

The core business activities of PetroSA are:

- exploration and production of oil and natural gas;
- participation in the acquisition of local as well as international upstream petroleum ventures;
- production of synthetic fuels from offshore gas;
- development of domestic refinery liquid fuels;
- logistical infrastructure and marketing and
- trading in oil and petrochemicals.

The key commodities produced include unleaded petrol, kerosene (paraffin), diesel, propane, liquid oxygen and nitrogen, distillates, eco-fuels and alcohols. PetroSA is mandated to commercialise all state-owned assets in the petroleum sector and to manage them as a profitable business for the benefit of all South Africans. The core strategic functions of PetroSA are to enable the Government of the Republic of South Africa to:

- improve the supply of fuel, oil and gas to the country;
- mitigate the impact of oil price variations and foreign currency fluctuations;
- drive transformation initiatives in the South African oil, gas and petrochemical value chain;
- champion, support and entrench the growth of Black Economic Empowerment (BEE) in the sector;

- manage the contingency crude oil reserves and the strategic petroleum assets of the Government of the Republic of South Africa;
- access upstream petroleum assets for the benefit of the Republic of South Africa and to
- operate PetroSA competitively in a sustainable commercial manner.

The New Age dated 31 May 2012 reported the following remarks by the Minister of Energy, Ms Dipuo Peters: '…our national oil company, PetroSA, has an important role to play towards ensuring that South Africa meets important goals of ensuring security of fuel supply for our country and it has to do so while it makes a profit without relying on the national treasury'.

1.2 LAYOUT OF THE PETROSA GTL REFINERY

Maintenance management at the PetroSA GTL Refinery is the responsibility of Reliability Engineering Services (RES), tasked to ensure optimum plant, machinery and equipment availability, reliability, maintainability and operability. RES consists of six maintenance areas allocated in the main production areas, namely Air and Gas Separation (AGS), Reforming (RFM), Synthol (SNT), Refinery (REF), Blending and Storage (B&S) and Offsites and Utilities (O&U). All six areas consist of mechanical, electrical and control systems, maintenance functions and disciplines that are responsible for the implementation, maintenance and optimisation of the MMS. Each maintenance discipline is managed by the area engineer/superintendent. The six production areas are managed by area production managers who have crews working shifts to implement, maintain and optimise the production and production out, (refer to Figure 1.2 below).

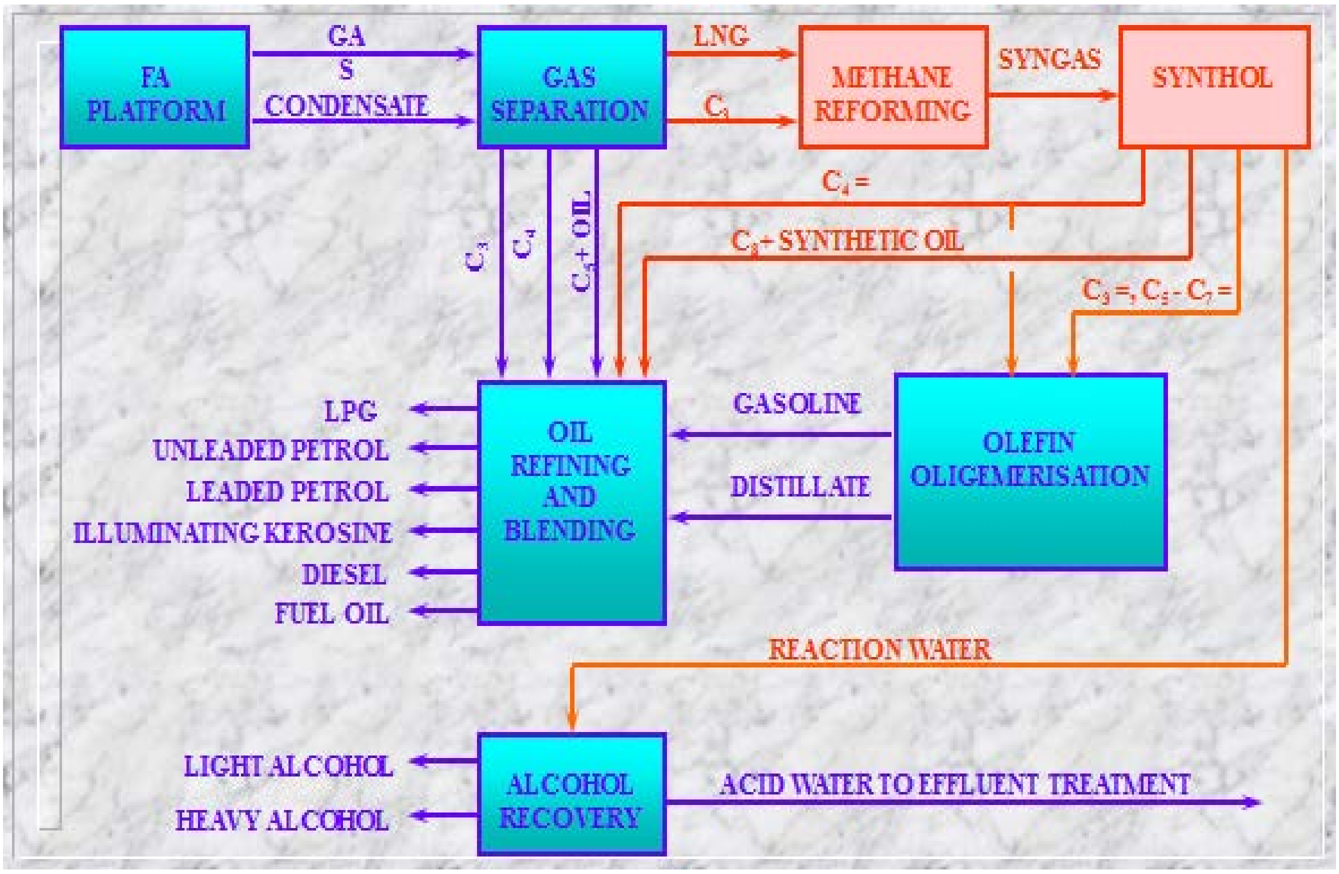

Figure 1.2 Layout of PetroSA GTL Refinery

1.3 MAINTENANCE MANAGEMENT SYSTEM (MMS) USED BY THE PETROSA GTL REFINERY

The PetroSA GTL Refinery uses the Risk Based Inspection (RBI) MMS. The system involves checking and/or inspection of equipment wall thickness and surface condition due to corrosion. It is designed for pipelines or pipe systems, tubes, vessels and tanks and excludes motors, pumps, conveyor belt systems, actuators, valves, mills, turbines, compressors, generators, transformers and other rotating equipment that requires periodic maintenance to sustain its life cycle. However, there is little, if any, preventive or predictive maintenance undertaken to prolong the life of the plant, equipment and machinery at the Refinery. In addition, the PetroSA GTL Refinery employs Risk Based Work Selection (RBWS) to prioritise breakdown maintenance activities on a daily basis. This system uses four decision dimensions namely,

- People − safety, risk and health dimensions, including fatalities, disabilities and injuries;
- Public image − impact on media and how the public and society views PetroSA and how the public will react if certain activities are performed or not performed;
- Environment − amount or number of product and/or material spillages;
- Business impact − monetary or cost impact due to failure or breakdown.

The higher the risk of consequence, the higher the priority given to the task or activity. The system is vulnerable to misuse by area production personnel, including production managers who use it to get service attention from workshops or service departments. As a result, the system does not address what it was designed to address but services those who are most vociferous. This system is also reactive and does not prevent breakdowns or failures but prioritises failures for execution purposes.

1.4 MMS MATRICES USED BY PETROSA GTL REFINERY

There are six maintenance key performance indicators (matrices) used by each discipline at the PetroSA GTL Refinery. The indicators are illustrated in Table 1.1:

Table 1.1 Matrices for PetroSA GTL Refinery

Key Performance Indicator (KPI)	**Target**
Backlog	Upper limit = 6 Crew Weeks Lower Limit = 2 Crew Week
Immediate Work	5%
Schedule Breakers	15%
Schedule Compliance	80%
Work Completed on Time	80%
Work order Analysis	No target

All these indicators are lagging: they measure and report past performance and the action from maintenance personnel is reactive.

1.5 STATUS OF THE PETROSA GTL REFINERY IN SUPPLY CHAIN

The total available production capacity for oil, gas and petrochemical products among the six refineries in South Africa is 692 000 barrels per day. The six refineries are:

- PetroSA GTL Refinery in Mossel Bay, with a capacity of 45 000 barrels per day: this is 6.5% of the available production capacity;
- Sapref in Durban, with a capacity of 180 000 barrels per day: this amounts to 26% of the available production capacity;
- Enref in Durban, with a capacity of 125 000 barrels per day: this is 18% of the available production capacity;
- Sasol Synfuels in Secunda, with a capacity of 150 000 barrels per day: this is 22% of the available production capacity;
- Natref in Sasolburg with a capacity of 92 000 barrels per day: this is 12.5% of the available production capacity;
- Calref in Cape Town with a capacity of 100 000 barrels per day: this is 15% of the available production capacity.

PetroSA GTL Refinery, the State-Owned Company (SOC), must compete with all of these private refineries to maintain its stake of 6.5% of the available production capacity. This requires healthy, reliable, available, maintainable and operable plant and equipment.

1.6 PETROSA GTL REFINERY, A STATE-OWNED COMPANY (SOC)

The Petroleum Oil and Gas Corporation of South Africa (PetroSA) is the national oil Company registered as a commercial entity under the South African Companies Act, Act No 71 of 2008. In addition, the Public Finance Act, Act No 1 of 1999, governs PetroSA. PetroSA is a subsidiary of the Central Energy Fund (CEF), which is wholly owned by the State and reports to the Department of Energy (DoE). The Companies Act, Act No 71 of 2008, defines an SOC as '…an enterprise that is registered in terms of this Act as a Company and is either:

- listed as a public entity in schedule 2 or 3 of the Public Finance Act, Act No 1 of 1999 or

- is owned by a Municipality as contemplated in the local Government Municipal Systems Act, Act No 32 of 2000 and is otherwise similar to an enterprise referred to in paragraph above'.

Schedule 2 of the Public Finance Act, Act No 1 of 1999 lists, amongst others, CEF (Pty) Ltd as one of the major public entities and at the end of it includes 'any subsidiary or entity under the ownership control of the above public entities'. PetroSA is under the control of CEF (Pty) Ltd and accordingly, it and all its subsidiaries and other entities under the control of CEF (Pty) Ltd will be regarded as a state-owned company. In terms of section 8 of the 2008 Companies Act, a profit company is a state-owned company, a private company, a personal liability or a public company.

1.7 PROBLEM STATEMENT

The challenge that the PetroSA GTL Refinery, SOC faces is increased pressure to function and perform as well as competition from private sector companies in terms of the achievement of optimum production output (PO) and profit maximisation, or profitability. In the petroleum industry, a company such as the PetroSA GTL Refinery must maintain its strategic importance for government fuel security but, at the same time, it must compete against private companies in terms of achieving high production volumes and maximising profitability. Thus, the problem is that the pressure to perform as well as private companies is on the increase and the PetroSA GTL Refinery needs to find better ways to manage its operations in order to fulfil its government mandate. It is suggested that improvements in the MMS can influence the achievement of optimum PO, which is essential for maximising profit in this competitive environment.

1.8 RESEARCH STATEMENT (HYPOTHESES)

Improvement of the MMS will have a positive impact on the achievement of optimum PO at the PetroSA GTL Refinery. This will assist in profit maximisation (PM) for the Refinery. Together they will affect the long-term sustainability of the company and its ability to fulfil its mandate to the people of South Africa.

1.9 RESEARCH OBJECTIVES

1.9.1 Primary objective

The primary objective of this study was to investigate maintenance management systems (MMS) and their impact or influence on PO and PM at the PetroSA GTL Refinery. Thus, the impact of the MMS as the independent variable on PO as the dependent variable will be investigated, as well as the effect of both MMS and PO on PM.

1.9.2 Secondary objectives

In order to achieve the primary objective, the following secondary objectives for this study were set:

- to identify and document the MMS at the PetroSA GTL Refinery;
- to identify the barriers and/or the causes which prevent the achievement of planned/scheduled PO at the PetroSA GTL Refinery;
- to analyse the problems in the MMS which may lead to interrupted PO at PetroSA GTL Refinery;
- to analyse the effect of interrupted PO on the maximisation of profit for the PetroSA GTL Refinery;
- to evaluate how the PetroSA GTL Refinery can improve its MMS to achieve planned/scheduled PO and PM;
- to recommend interventions to improve MMS, to achieve planned/scheduled PO and PM for the state-owned company PetroSA GTL Refinery.

1.10 LITERATURE REVIEW

1.10.1 Literature Review

The aim of the literature review was to report on existing knowledge on the constructs MMS, PO and Profitability and to understand the relationship between these constructs. The literature study would also provide a better understanding of what asset management, maintenance, MMS, production, PO and PM entail. In order to conduct this research, current books, published conference proceedings, scientific journals, research reports, company documents, government policies, regulations and standards, experts in asset management, maintenance and production management, previous M&D dissertations and recognised internet articles were consulted and utilised.

Peters (2002b:3) states that the high cost of gambling with maintenance may become a catastrophic failure that causes loss of innocent lives, time, profits or service. He further insists that gambling with maintenance costs is not an option when the enormous potential from improving maintenance activities and wise investment is fully understood. As mentioned earlier, the PetroSA GTL Refinery has to perform as well as private companies and has to fulfil the government mandate while competing with private refineries.

Peters (2002b:3) also states that gaining full value from physical or capital assets is an important challenge for organisations operating in increasingly competitive environments, where production interruptions due to equipment failures lead to expensive repair costs and lost revenue opportunities. He claims that maintenance within the manufacturing operations has a major impact on profit, throughput and quality. He further highlights that the impact can easily be negative but with focused investments and continuous reliability, the impact can conversely have a positive impact on the bottom line and profit optimisation. Ross (2005:17), points out that better utilisation and asset performance applies to everyone in the organisation and there is no end to the process. She further insists that this should be the focus of all managers. Ross (2005:19) also maintains that improving asset management is difficult and that it is not something that is done for three months and then the project is finished. Asset management (AM), as she contends, is a commitment that must be upheld over a number of years and improvements should not be seen as a 'nice thing to do': asset management should instead be based on sound commercial reasons.

Wilson (2011:10) mentions operational losses, compliance losses, safety of people, breakdown costs and replacement costs as consequences of unreliable plant, equipment and machinery. He further claims that quality standards, purchase specifications, economic life cycle, planned maintenance, tactics and targets are the cost of reliability. A review of the literature indicated that there are various definitions of maintenance, asset management, maintenance management systems (MMS), production, PO and profit maximisation (PM) which will be discussed in the next section.

1.10.2 Definitions of asset management (AM), maintenance, MMS, PO &P

1.10.2.1 Asset management (AM)

Kelly (2002:13) defines asset management as '…a coordinated management of the design, procurement, use and maintenance of a firm's fixed assets, in order to maximise the contributions to the firm's profit over the life cycle of those assets'. Ross (2005:3) defines asset management as '…the oversight of the life of an asset to achieve optimum life cycle cost with the maximum availability, performance efficiency and the highest of quality – asset provision, asset operation and asset care'. Kelly (2006;12-13), defines capital asset management as '…a combination of management, financial, engineering and other practices applied to physical assets in pursuit of economic life cycle costs'. He further elaborates on his definition that asset management '…is concerned with the specifications and design for reliability and maintainability of the plant, machinery, equipment, building and other structures with their installation and replacement, design, performance and costs'.

Based on the above-mentioned definitions for the purpose of this research, asset management was defined as '…improving asset life in terms of <u>asset health</u> (reliability, availability, maintainability and operability of plant, machines and equipment), <u>asset performance</u> (effectiveness, utilisation, efficiency and production volumes of plant, machines and equipment) and <u>asset provision</u> (production sales, revenue, ROI, and profit) to the benefit of its stakeholders'. A clear link exists between this definition of asset management and the Maintenance Scorecard (MS) assessment tool that will be discussed in section 1.10.2.6 below. The next section investigates the definitions of maintenance.

1.10.2.2 Maintenance

Hughes (2001:197) defines maintenance as '…the action required for restoring or maintaining an item in serviceable condition, including servicing, repair, modification, overhaul inspection and determination of condition'. Kirster and Hawkins (2006:309) define maintenance as '…the routine, recurring upkeep required to keep facilities and equipment in a safe, effective condition enabling it to be utilised at original design capacity and efficiency or some other level specified by management as the maintenance objective'. Kelly (2006:267) defines maintenance as '…the combination of all technical and associated administrative actions intended to retain an item in, or restore it to, its state in which it can perform it's intended or required function'.

With due consideration to the multitude of definitions, for the purpose of this study, maintenance was defined as '…the function of keeping items or equipment in, or restoring them to serviceable condition, including servicing, testing, inspection, adjustment, alignment, removal, replacement, re-installation, troubleshooting, calibration, condition determination, repair, modification, overhaul, rebuilding, and reclamation'. The link between the definition of maintenance and the MS tool is evident and will be discussed in section 1.10.2.6 below.

As stated previously, the focus of this study was on the impact of the MMS on PO&P at the PetroSA GTL Refinery. The next section investigates the definitions of the MMS.

1.10.2.3 Maintenance Management System (MMSs)

Hughes (2001:129) lists Computerised Maintenance Management Systems (CMMS), performance indicators, shutdown planning and work control, scheduling and feedback as core MMSs. Kelly (2006:36-37) defines MMS as '…budgetary control, maintenance performance measurement and control, plant reliability control, short-term maintenance work planning and work control, long-term maintenance planning and work control (turnaround management), equipment spares management and maintenance documentation'. Peters (2006:100) claims that continuous reliability improvement (CRI), reliability centred maintenance (RCM), and total productive maintenance (TPM) are MMSs.

For the purpose of this study and following on the above-mentioned definitions, MMS was defined as '…the systems that have a major influence on maintenance function in terms of budgetary control, performance measurement and control, plant reliability control, maintenance organisational efficiency control, short and long term maintenance work planning, scheduling, coordination and control, equipment spares management and document management'. A clear link exists between this definition of MMS and the MS tool, which will be discussed in section 1.10.2.6 below. The next section describes the definitions of production and production output (PO).

1.10.2.4 Production and Production Out

Evans and Collier (2007:82) define production as '…the ratio of output of a process to the input'. They further claim that PO is easier to measure for goods and services. They maintain that goods output can be stated in physical units such as parts, tons or finished tangible units, whereas services outputs are often based on customer perception of service and are intangible.

For the purpose of this research production was defined as '…the creation of goods and services' and the production out is defined as '…the goods and/or services resulting from the production process'. A clear link exists between this definition of production, PO and the Maintenance Scorecard (MS) tool, which will be discussed in section 1.10.2.6. The next section investigates definitions of profit maximisation and/or profitability.

1.10.2.5 Profit Maximisation (PM)

Gitman (2000:617) defines profitability as ' the relationship between revenues and costs generated by using the firm's assets, both current and fixed in productive activities'. Firer, Ross, Westerfield and Jordan (2004:9) list the following as possible goals of financial management in a company. The goals are: surviving, avoiding financial distress and bankruptcy, beating the competition, maximising sales or market share, minimising costs, maximising profits and maintaining steady growth in profits.

A clear link exists between the definition of PM and the Maintenance scorecard (MS) assessment tool that will be discussed below.

1.10.2.6 Maintenance Scorecard (MS)

The MS was originally developed as the Scorecard for Excellence in 1981 by The Management Excellence Institute (TMEI), an alliance of highly qualified individuals and organisations with technical knowledge and practical experience established to develop excellence in maintenance and physical asset management.

The MS has six perspectives or parts (Mather, 2005:32). He further defines the six perspectives or parts as follows:

- Productive perspective – How can asset management, maintenance and MMS contribute to the ability to produce more?
- Learning perspective – How can the organisation continue to be innovative and use asset management, maintenance and MMS as an area of growth?
- Quality perspective – How can the organisation ensure the repeatability of performance of physical assets?
- Environmental perspective – What can be done to ensure that corporate exposure to environmental incidents is within tolerable limits?
- Safety perspective – What can be done to ensure that corporate exposure to safety incidents is within tolerable levels?
- Cost perspective – How can the organisation continue to reduce the unit costs of the asset management, maintenance and MMS efforts?

Peters (2006:51) claims that the MS provides a means to evaluate how the six key resources, namely people, technical skills, physical assets, information and parts/materials are managed.

For the purpose of this research, the following is the departure point and serves as an example to indicate the gaps that may be identified through the MS:

'If plant, equipment and machines continuously produce less than 45 000 barrels of petrochemicals per day, then a large gap exists between expected output of 45 000 barrels per day and the actual PO.' Given that this gap is large, PO (efficiency, operability, quantities or volumes) lies in addressing MMS (availability, reliability, maintainability and operability) first. Therefore, asset performance depends on asset health.

In evaluating the MS tool, the following potential drawbacks were considered. Geitner and Galster (2000) point out that if enterprises choose to ignore information technology, the design and implementation of the MS will fail. Mather (2005) states that inadequate linking of metrics to the corporate objectives of the company leads to the failure of the MS. In addition, he agrees and confirms that using one specific measure to understand the effectiveness or overall performance of the plant or equipment will lead to the failure of the MS.

Despite the MS tool drawbacks, the following advantages are presented. Peters (2002a) indicates that there are many benefits identified when using the MS and among other benefits are improved planning, improved work control, enhanced preventive and predictive maintenance, improved parts and material availability, improved reliability analysis, increased budget accountability, increased capacity to measure performance and service, and increased level of maintenance information.

The previous section discussed the drawbacks and potential advantages of MS as a research tool. Since the advantages outweigh the disadvantages, MS was deemed to be the most appropriate tool for this study.

The following section focuses on the research design applied in this study

1.11 RESEARCH DESIGN

Welman and Kruger (2003:18) list the following as the purpose of research:

- to describe how things are and to define the nature of the study object,
- to explain why things are the way they are and the relationship between things and
- to predict phenomena, such as human behaviour in the workplace, with the aim of using this information.

Mouton (2006:56) states that the research design focuses on the end product, that is: the kind of study being planned and the kind of result aimed for. It also focuses on the logic of research, that is: the kind of evidence required to address the question adequately. Welman, Kruger and Mitchell (2011:2,102) state that the research is a process that involves obtaining scientific knowledge by means of various objective methods and procedures. It concerns the plan to obtain appropriate data for investigating the hypothesis and/or research question. The study will utilise the quantitative research methodology and the research paradigm. The reasons for using the quantitative research methodology are listed below:

- the questionnaires comprise numerical values from 1 to 5 to rate the response of the maintenance and operations groups (primary data) and
- the data used for PetroSA GTL Refinery profitability for the past five years comprises numerical values (secondary data).

The quantitative approach places greater value upon information that can be numerically manipulated in a meaningful way and it is the traditional scientific approach to research (Page and Meyer 2003:17). The qualitative approach can be conceptualised as a focus on words and feelings; the quality of an event or experience (Page & Meyer, 2003:18). According to Welman *et al.* (2011:8), the aims of qualitative research methods are to establish the socially constructed nature of reality to stress the relationship between the researcher and the object of study as well as to emphasise the value-laden nature of the enquiry.

Quantitative research methods do not involve the investigation of processes but emphasise the measurement and analysis of the causal relationship between variables within a value-free context (Welman *et al.*, 2011:8). The purpose of quantitative research is to evaluate object data consisting of the numbers while qualitative research deals with subjective data that are produced by the minds of respondents or interviewees (Welman *et al.*, 2011:8).

The study was conducted using the positivism research philosophy. Cameron and Price (2009:73) state that positivism is linked to a belief phenomenon that exists independently of the observer and can be detected through direct observation. The researcher followed a deductive approach to conduct this study. According to Cameron and Price (2009:751), deductive research starts with a theory and proceeds by testing hypotheses derived from the theory. Lastly, the study followed a cross sectional methodology. According to Hair, Celsi, Money, Samuoel and Page (2001:121), the cross sectional analysis is used when a researcher wants to compare findings across various clusters or market segments at a particular time to identify points of difference or similarities in performance or response patterns.

1.11.1 Empirical research

The study focuses on the impact of the MMS on PO and profitability at the PetroSA GTL Refinery. The total number of crew (manpower) for maintenance was 140 and for production, it was 96. This was the total size of the research population available. For the purposes of the study, 40% of the 140 of the maintenance employees and 40% of the 96 production employees were consulted and given the opportunity to complete questionnaires. The demographics were based on the trade or designation and coded as follows:

(a) Maintenance group: consisting of artisans, maintenance supervisors, reliability technicians, reliability engineers, maintenance planners and reliability managers and

(b) Production Group: consisting of process controllers, financial officers, production planners, production superintendents and production managers (primary data).

Table 1.2 shows the maintenance group and Table 1.3 shows the Production Group populations. All questionnaires for MMS and PO were distributed to the PetroSA GTL Refinery site electronically using the Microsoft Outlook email facility system. The questionnaires were typed on a Microsoft Excel spreadsheet to permit easy editing on the computer. Questionnaires were then sent by email to respondents. The name list used is for the entire group or discipline, that is, the DL MB Maintenance Plan is the group for all maintenance planners. Other questionnaires were printed and physically distributed to respondents by the researcher to afford both the researcher and respondent opportunity to interact.

The respondents deposited completed questionnaires into a sealed box that was placed in a secure location with security cameras and personnel manning the area. The sealed boxes were collected on a specified date from the secured location for processing. The researcher further utilised data and information on the quantity of products planned per month versus the quantity of actual products manufactured per month, the cost reports and the annual financial reports (secondary data). For the MS surveys, the researcher considered the six areas of PetroSA where maintenance on assets and production is carried out.

Participants with sufficient exposure to MMS and production management provided meaningful feedback regarding MMS, PO and profitability. The study was completed during the period May 2014 to August 2014 (see Tables 1.2 and 1.3 for explanation of the sampling method). Both groups (Maintenance Group and Production Group) completed the MS questionnaires. The MS assessment tool was pre-tested on respondents who fitted the profile of the Maintenance and Production Groups. This was done to ensure that both assessment tools were understandable, which would increase the reliability of the data collected.

1.11.2 Research Population

The PetroSA GTL Refinery comprises of AGS, RFM, SNT, REF, B&S and O&U production areas in which maintenance of assets is carried out. The scope of the study was centred on all the above six areas. The MS questionnaires were electronically distributed to the Maintenance and Production Groups via Microsoft Outlook email. Tables 1.2 and 1.3 indicate the method of proportionate stratified sampling that was used to select the ideal number of participants to take part in the survey. According to Welman and Kruger (2003:56), the stratified sampling method implies that the population is divided into sub-groups (strata) and random samples are then drawn from each sub-group.

For the purpose of this study, the populations were segmented according to two groups: the first group represented the Maintenance Group, which comprised 40% of the 140 maintenance employees and management. The second group represented the Production Group, which was 40% of the total 96 operations employees and management. This offered an opportunity to gain a representative view of maintenance and production personnel experiences for AM, maintenance, MMS, production, PO and profitability at the Refinery. The PetroSA GTL Refinery, a SOC, is regulated by government legislation, therefore such a study was imperative to ensure competitiveness and survival. The rationale behind having two distinct population groups was based on:

- different perceptions on what, how and when machines and equipment plant should be serviced or maintained;
- different interpretations, views and understandings of asset management, maintenance, MMS between both groups;
- the largest number of employees between the two groups, namely Maintenance and Operations;
- direct involvement of these two groups in both MMS, PO and profit maximisation/profitability at the PetroSA GTL Refinery.

Table 1.2 Proportionate stratified sampling of Maintenance personnel

Proportionate stratified sampling of 56 maintenance employees (numbers based on 2013 organisational structure).

Item No	Population Segment	Population Size (N) Maintenance Group	Sample Size (n)	Calculations
1.0	AGS	20	8	56 X 20 /140
2.0	RFM	20	8	56 X 20 /140
3.0	SNT	22	9	56 X 22 / 140
4.0	REF	32	13	56 X 32 / 140
5.0	B&S	20	8	56 X 20 / 140
6.0	O&U	26	10	56 X 26 / 140
7.0	**Total**	**140**	**56**	**140 X 40%**

Table 1.3 Proportionate stratified sampling of production personnel

Proportionate stratified sampling of 38 production employees (numbers based on 2013 organisational structure).

Item No	Population Segment	Population Size (N) Operations Group	Sample Size (n)	Calculations
1.0	AGS	17	7	38 X 17 / 96
2.0	RFM	13	5	38 X 13 / 96
3.0	SNT	21	8	38 X 21 / 96
4.0	REF	20	8	38 X 20 / 96
5.0	B&S	12	5	38 X 12 / 96
6.0	O&U	13	5	38 X 13 / 96
7.0	**Total**	**96**	**38**	**96 x 40%**

1.12 DATA ANALYSIS

Since a random sample was drawn, the data were analysed by means of correlation analysis.

1.13 LIMITATIONS

The rules, regulations and policies of the PetroSA GTL Refinery regarding handling of data and information limited the researcher's ability to gather, collect, capture, retrieve and compile a research report because it was against company policy to utilise classified data and information for public and study purposes. Management was uncomfortable that their subordinates and themselves utilised company time to complete questionnaires and as a result, this minimised the number of respondents or population. Time to complete questionnaires was a limitation because the company was planning four plant outages for maintenance purposes in February 2014 and July 2014 and this also impacted on the availability of role players, as their time was limited.

The risks were prevented or avoided by engaging with the participants and explaining the objective of the research project upfront to ensure that they fully understood the need for and objectives of the research. An alternative solution was to elicit leadership buy-in and support to assist in motivating participants during team meetings and gatherings to take part in this study voluntarily. The researcher is of the opinion that these interventions did not hamper the objectivity of the participants completing the questionnaires, hence, management motivated the whole team and was not aware who participated. Affiliation to professional associations like the South African Asset Management Association (SAAMA), PRAGMA, Planning Planet, Planning Engineer, Shutdown and Primavera groups assisted the researcher to gain access to AM, MMS, Production, PO and PM related books, journals, magazines and articles via internet websites.

1.14 VALUE OF THE STUDY

The research could well be the first of its kind at the PetroSA GTL Refinery and the researcher felt that the study would add value to the PetroSA GTL Refinery (on which the study was based) in terms of implementing and sustaining the MMS and improving plant and equipment reliability, availability, operability and maintainability. The researcher is of the opinion that the MS assessment tools could become a continuous improvement process at the PetroSA GTL Refinery; they could also be applied to Head Office, Voorbaai, depots, FA-Platform, Logistics Base and Orca and the study could add value to PetroSA for developing and improving maintenance, asset management, maintenance planning, scheduling, coordination, work control and production management in relation to manpower skills, commitment, awareness, leadership and cross-functional coordination as well as providing essential information and knowledge to the staff and leadership. PAS 55-2 (2008:VII) points out that good asset management plays a vital role to define clear direction, provide leadership, encourage staff awareness, ensure competency, commitment and cross-functional coordination.

1.15 CHAPTER LAYOUT

Chapter 1: General Overview

Chapter 1 will provide a brief overview of the background of the study and the problem statement, or hypothesis. It will also outline the purpose of the research and research objectives, the research method, definitions and abbreviations.

Chapter 2: Asset Management and Maintenance

Chapter 2 forms part of the literature review, focusing on asset management and maintenance. Definitions and previous research in terms of asset management and maintenance will be investigated. The importance of asset management and maintenance will be discussed.

Chapter 3: MMSs

Chapter 3 forms part of the literature review, concentrating on MMSs. Definitions and previous research in terms of MMSs will be investigated. The chapter will give an in-depth overview of the MS tool that will be used to conduct the study. The importance of MMS will be discussed.

Chapter 4: Production and Profit

Chapter 4 forms part of the literature review, focusing on production and profit. Definitions and previous research in terms of production and profit will be investigated. The chapter will give an in-depth overview of the transformation process model, main production processes, production process performance measurement, the theories of profit and the function of profit.

Chapter 5: Research design

Chapter 5 will describe the research design, including the research strategy adopted, data collection methods, data analysis, research quality and delimitations and research ethics.

Chapter 6: Findings

Chapter 6 will discuss the analysis of the collected data

Chapter 7: Conclusion

Chapter 7 will be a concluding overview on the impact of MMS on PO and profitability at the PetroSA GTL Refinery. The findings in Chapter 6 will be discussed in relation to the research objectives, the shortcomings and the recommendations for further research will be presented.

1.16 CHAPTER SUMMARY

This chapter served as a general overview to the study. It addressed the background to the study, the problem statement, the objectives of the study, the project scope and constraints (limitations and value), the methodology of the study, the data collection approach and methodology and the background of the PetroSA GTL Refinery.

Chapter 2 will introduce the status of asset management and maintenance in developed and developing countries, asset management framework, asset management and challenges, maintenance strategies, maintenance cycle, maintenance challenges and maintenance best practices.

Chapter 2: ASSET MANAGEMENT AND MAINTENANCE

2.1 INTRODUCTION

Chapter 1 indicated that the primary objective of this study was to investigate the impact of the improvement of the maintenance management system (MMS) on achieving the planned and scheduled production output (PO). In support of this objective, the purpose of this chapter is to:

- present a brief report on the status of asset management and maintenance in selected developed and developing countries;
- introduce the concept of asset management framework at the PetroSA GTL Refinery;
- introduce the maintenance cycle at the PetroSA GTL Refinery;
- provide a brief overview of the importance and criticality of asset management, maintenance and the best practices and standards.

Since this chapter provides the context for this study, it should be emphasised that only an overview of asset management framework, asset management challenges, maintenance cycle and best practices is provided so as not to deviate from the main purpose of the study. The main themes of this chapter are depicted in Figure 2.1.

CHAPTER 2: ASSET MANAGEMENT AND MAINTENANCE

2.1 INTRODUCTION

2.2 DEFINITIONS OF ASSET MANAGEMENT AND MAINTENANCE

2.3 STATUS OF ASSET MANAGEMENT AND MAINTENANCE IN SELECTED DEVELOPED AND DEVELOPING COUNTRIES

2.4 ASSET MANAGEMENT FRAMEWORK

2.4.1 Systems and Procedures perspective

2.4.2 Execution perspective

2.4.3 Technical perspective

2.4.4 Financial perspective

2.4.5 Asset Management challenges

2.5 MAINTENANCE

2.5.1 The Maintenance Cycle

2.5.2 Challenges of Maintenance

2.5.3 Maintenance best practices

2.6 CHAPTER SUMMARY

Figure 2.1 Layout of Chapter 2

It is evident from literature that there are plenty definitions of asset management and maintenance; several definitions were presented in Chapter 1. This section will briefly expand on additional definitions of asset management and maintenance that have been proposed by several authors.

2.2.1 Asset management

PAS 55-1 (2008:V) defines asset management as '…systematic and coordinated activities and practices through which an organisation optimally and sustainably manages its assets systems, their associated performance, risks and expenditures over their life cycles for the purpose of achieving its organisational strategic plan'. TMEI (2013:11) defines asset management as '…the systematic planning and control of a physical inventory value resource throughout its economic life, the systematic planning and control of a physical resource throughout its life and this may include the specification design and construction of the asset, its operation, maintenance and modification while in use and its disposal when no longer required'.

Following on the common themes of these definitions, it was proposed in Chapter 1, section 1.10.2.1 that for the purpose of this study, asset management would be defined as '…improving asset life in terms of asset health (reliability, availability, maintainability and operability of plant, machines and equipment), asset performance (effectiveness, utilisation, efficiency and production volumes of plant, machines and equipment) and asset provision (production sales, revenue, ROI, and profit) to the benefit of its stakeholders' as in Figure 2.2 below:

2.2.2 Maintenance

Nyman and Levitt (2010:312) define maintenance as '…the act of holding or keeping in a preserved state'. Slack, Chambers and Johnston (2010:588) define maintenance as '…how organisations try to avoid failure by taking care of their physical facilities'. They further highlight that maintenance is an important part of most operations' activities, particularly in operations dominated by physical facilities such as power stations, hotels, airlines and petrochemical refineries. Nyman *et al*. (2010:IX) state that maintenance is a source that contributes to the achievement of profit objectives. Heizer and Render (2011:682) define maintenance as '…the activities involved in keeping a system in working order. McKeown (2012:6) argues that asset management is not part of maintenance, but maintenance is the key part of the whole life of the asset. TMEI (2013:11) defines maintenance as '…the function of keeping items or equipment in, or restoring them to, serviceable condition'.

TMEI (2013:11) reports that maintenance includes servicing, test, inspection, adjustment, alignment, removal, replacement, re-installation, troubleshooting, calibration, condition determination, repair, modification, overhaul, rebuilding and reclamation. Abdul Samat, Kamaruddin and Andul Azid (2012:93) conclude by mentioning that maintenance is done to ensure that machines are in good condition, serviceable and operationally safe for producing quality products. Saltzer (2012:2) says that maintenance management can significantly create or destroy the value in an organisation through performance of the assets, cost control measures, inventory management or securing and maintaining the licence to operate. Stevenson (2012:655) defines maintenance as '…the activities that maintain facilities and equipment in good working order so that a system can perform as intended'. Starr (2012:6) claims that boosting reliability and availability at optimal cost is the very essence of competition. He further maintains that good maintenance is a pre-requisite for good services (quality) and production (volumes).

Following on the common themes of these definitions, it was proposed in Chapter 1, section 1.10.2.2 that for the purpose of this study, maintenance would be defined as'…the function of keeping items or equipment in, or restoring them to serviceable condition, including servicing, testing, inspection, adjustment, alignment, removal, replacement, re-installation, troubleshooting, calibration, condition determination, repair, modification, overhaul, rebuilding, and reclamation' as outlined in Figure 2.2 below:

Asset Management Model

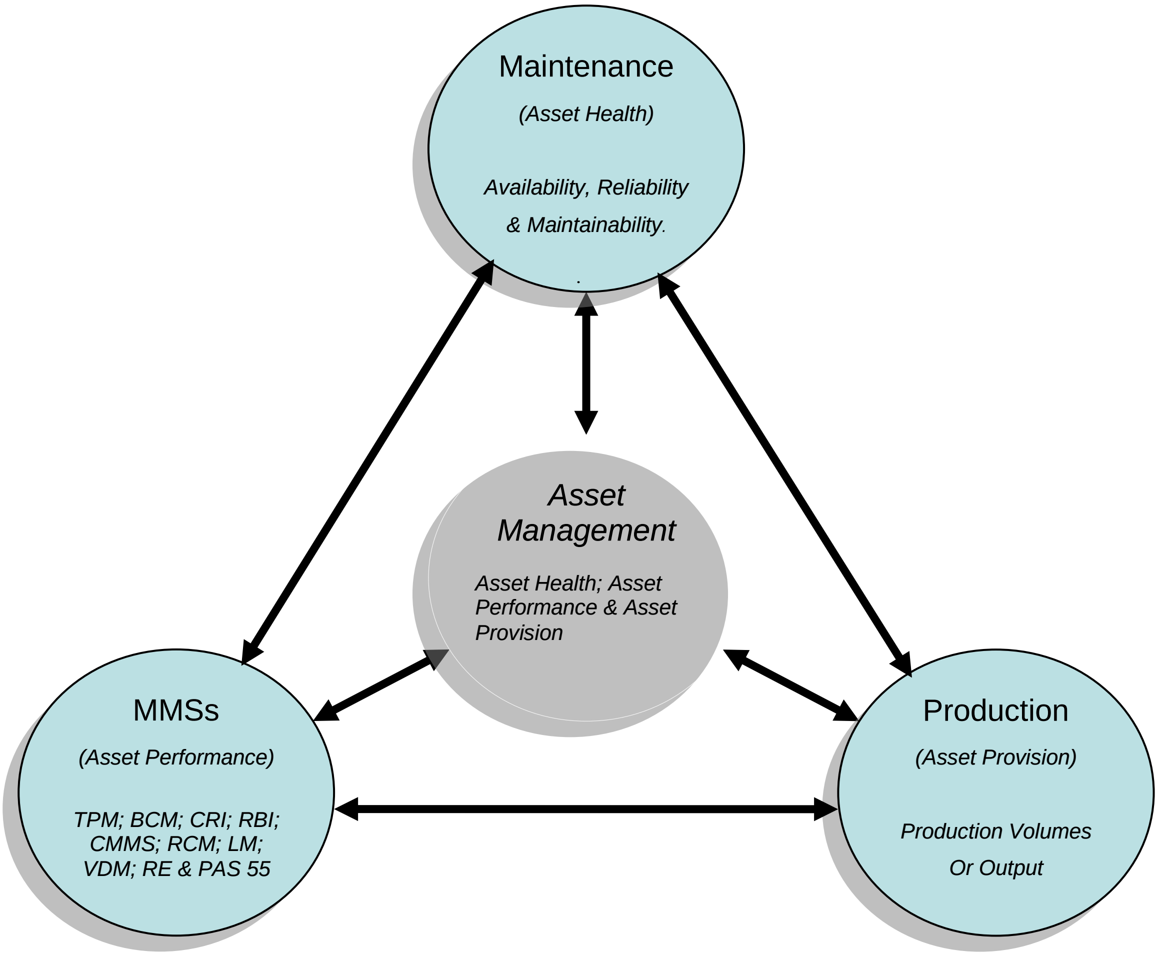

Figure 2.2 Asset Management Model
(Source: Ross, 2005:3)

2.3 THE STATUS OF ASSET MANAGEMENT AND MAINTENANCE IN SELECTED DEVELOPED AND DEVELOPING COUNTRIES

Asset management and maintenance is growing worldwide, especially in countries where it was non-existent. In countries such as North America, South America, Europe, Asia and Australia asset management and maintenance has a long history. According to Hughes (2001:7), the history of maintenance is characterised by the following:

- First generation maintenance: downtime did not matter much and prevention of equipment failure was not a high priority;
- Second generation maintenance: reliability of equipment became a focus and prevention of equipment failure (preventive maintenance) became a high priority and
- Third generation maintenance: Just-In-Time (JIT) system was introduced and reliability, availability, environmental and safety consequences became a priority.

The Global Forum for Asset Management and Maintenance (GFAMM, 2011:5) concurs and adds that asset management has developed significantly over the two decades and a number of approaches, standards, models and principles have been developed across the globe. The maintenance world is evolving and new methods, processes and techniques are constantly being developed, tested and implemented. Every company wants to produce as much as possible at the lowest cost with the highest return, at the best efficiency rate and without running their assets into the ground (Peterson, 2013:1). According to Peterson (2013:2), industries in North America seem to be improving as maintenance programmes are implemented; however, 75% of companies are still in breakdown maintenance mode (corrective maintenance). Petrochemical companies are doing well while mining and metal industries are still far behind. In South America, there seems to be a strong focus in maintenance improvement and this is indicated by the rapid growth of maintenance organisations. In Europe, most companies and professionals are interested in maintenance model and theory but there is much more talk than action in maintenance improvement. In Australia, maintenance has always been a major focus. Advanced training programmes in maintenance and reliability are available. Asia is primarily focused on discrete manufacturing and total productive maintenance is part of their culture. In China, there is very little focus in maintenance improvement. In India, maintenance focus is very weak. In Russia, there is a very strong focus on maintenance improvements. In the Middle East, there is a poor and weak maintenance improvement culture. In North Africa, much of the maintenance is related to the learning from the major oil companies and in South Africa, the culture of maintenance improvement exists, but it is compromised by education levels (Peterson, 2013:2).

The following section deals specifically with asset management framework, asset management challenges, maintenance, maintenance cycle, challenges in maintenance and the maintenance best practices.

2.4 ASSET MANAGEMENT FRAMEWORK

Improving asset management is difficult but not impossible and this section deals with the requirements, systems and procedures necessary for the successful implementation of asset management. According to Ross, (2005:5) the asset management framework consists of the following four pillars as indicated in Figure 2.3 below.

- Systems and Procedures Perspective;
- Execution Perspective;
- Technical Perspective and
- Financial Management Perspective.

The Global Forum on Maintenance and Asset Management (GFMAM, 2011:13) identifies the following key asset management principles:

- assets exist to provide value to the organisation and its stakeholders;
- people are the key determiners of asset value realisation;
- an asset management organisation is a learning organisation;
- asset management requires understanding of the organisation's operating context and opportunities;
- asset management decisions consider both short-term and long-term economic, environmental and social impacts and

- asset management transforms strategic intent into technical economic and financial decisions and actions.

The Asset Management Framework Model

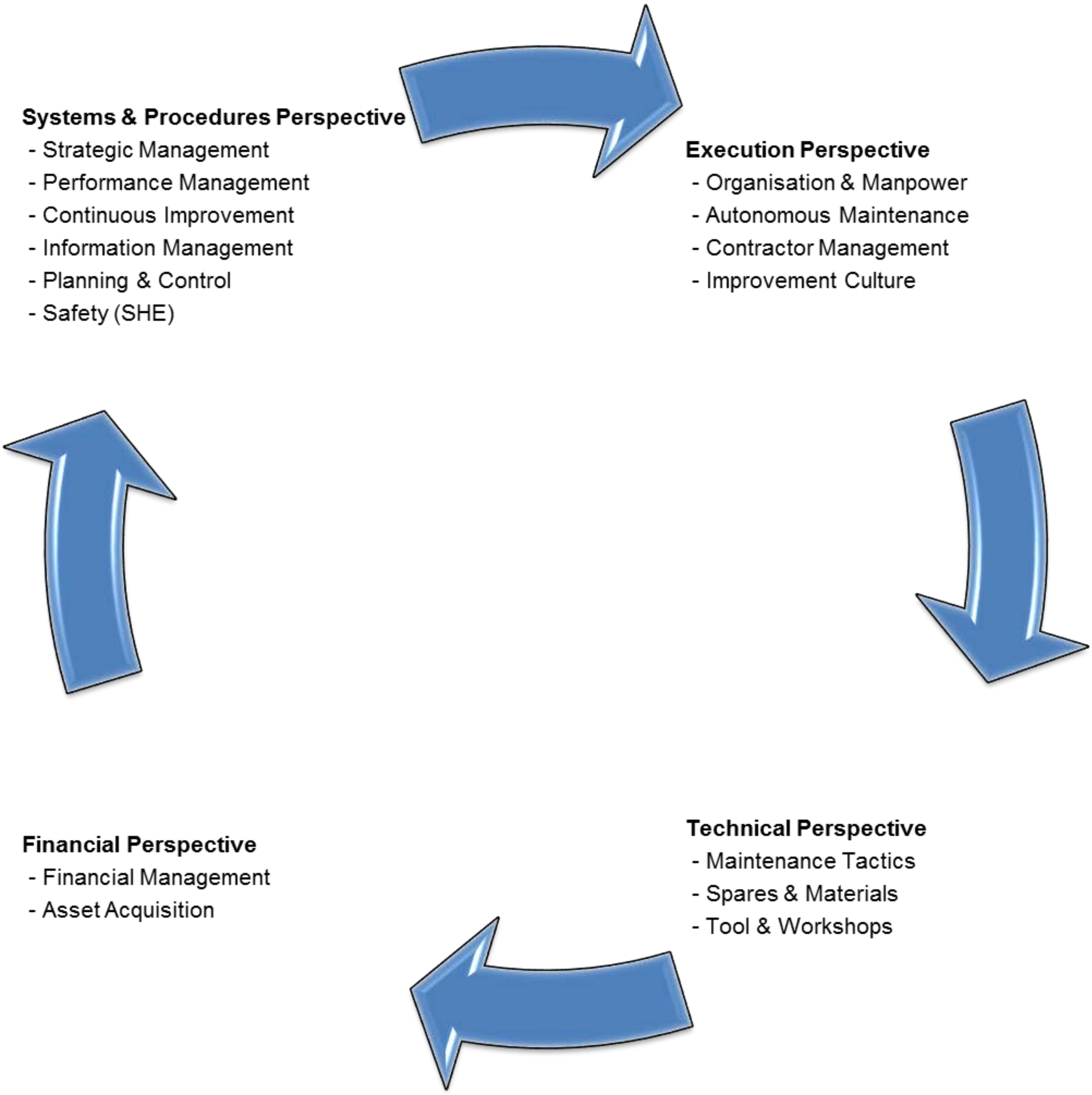

Figure 2.3 Asset Management Framework
(Source: Ross, 2005:3)

2.4.1 Systems and procedures perspective

This section addresses the six characteristics of formulating and implementing effective and efficient systems and procedures for asset management. The characteristics are: strategic management, maintenance performance measurement, continuous improvement, information management, maintenance work planning and control and safety, health and environment. These characteristics will be discussed in detail in the next sections.

2.4.1.1 Strategic management

Strategic management is a structured process for the development and management of the asset policies and procedures for the communication, implementation, measurement and review of the asset management strategy. The objective is to enable the enterprise to accomplish short-term, medium-term and long-term objectives (Ross, 2005:6). The asset management strategy converts the objectives of the organisational strategic plan and the asset management policy into a high level, long-term action plan for the assets and/or asset systems, the asset portfolios and/or the asset management system. The high-level long-term action plans for the assets and the asset management objectives are normally the outputs of the asset management strategy. These elements together form the basis for developing more specific and detailed asset management plans (PAS 55-1, 2008:2).

2.4.1.2 Maintenance performance measurement

The performance measurement process is the structured approach and technique for measuring the effectiveness of assets. It includes the systems, policies and procedures for the identification of measurements, the setting of targets, the measurement and displaying as well as the analysis and interpretation of measured results (Ross, 2005:5). Maintenance performance measurements should measure or evaluate craft labour, planning and scheduling, planned maintenance, asset reliability, equipment effectiveness and costs (Peters, 2006:87).

Asset management performance measurement includes measuring the effectiveness of the organisation's asset management system. It may include the effectiveness of expenditures, the reliability, efficiency, quality sustainability and value of the assets and their utilisation and/or the impact of assets and asset management upon the organisation's financial performance, health and safety performance, environmental performance, compliance and reputation. Results are measured against the organisation's strategic plan, asset management policy, asset management strategy, asset management objectives and/or asset management performance requirements (PAS 55-1, 2008:2).

2.4.1.3 Continuous improvement

Goals are important but improvement is the name of the game (Hughes, 2001:142). Continuous improvement means negotiating goals, achieving goals and extending goals (Hughes, 2001:156). Lastly, Hughes identifies the following features for continuous improvement:

(1) Management views the performance level of the organisation as something to be continuously challenged and incrementally upgraded;

(2) Management views the contribution and role of its workforce as extremely important.

Continuous improvement is a structured approach to continually improve asset management performance. It includes the systems, policies and procedures for prioritising and the analysis of performance gaps, development and execution of improvement plans, as well as formalising and establishment of best practices. Continuous improvement enables the enterprise to optimise the maturity of the asset management function (Ross, 2005:7). According to Peters (2006:247), continuous reliability improvement is an overall strategy committed to the improvement of the total maintenance operation as a business.

2.4.1.4 Information management

All plants require a system of collecting, compiling and interpreting data that defines the effectiveness of all plant functions. This system must be capable of providing timely and accurate performance statistics that can be utilised to plan, schedule and manage the plant (Cato & Mobley, 2002:137). Information management is the effective management of all data and information in the asset management function.

This includes the systems, policies and procedures for identification, gathering, controlling, analysis, feedback and reporting as well as the utilisation of data and information.

The objective of information management is to enable the enterprise to make informed asset management decisions (Ross, 2005:7). According to PAS 55-1 (2008:13), organisations are expected to establish, implement and maintain procedures for controlling all required information. The following are the minimum requirements for information management:

- The adequacy of the information must be approved by authorised personnel before it is used;
- Information is maintained and adequacy assured through periodic reviews and revisions;
- Appropriate roles, responsibilities and authorities regarding the organisation, generation, capture, maintenance, assurance transaction, rights to access, retention, archiving and disposal are allocated;
- Obsolete information is promptly removed from all points of issue and points of usage;
- Archival information retained for legal or knowledge preservation purposes is identified and
- Information is secured and, if in electronic form, it must be backed up and be recoverable.

2.4.1.5 Maintenance work planning and control (WP&C)

Planning determines what needs to be done by whom and by when in order to fulfil one's assigned responsibility (Kerzner, 2003:380). Planning is the process of identifying scope, developing milestones, cost and scheduling, detailed planning and resource identification (Hughes, 2004:140). WP&C is the structured process to plan and control all maintenance tasks. This includes the systems, policies and procedures for the planning and scheduling of maintenance activities, the allocation of resources, the execution, reporting and feedback as well as the quality control of the work. The objective of WP&C is to enable the enterprise to optimise resource utilisation on all maintenance tasks (Ross, 2005:8).

Maintenance planning is how to do the job, the advanced preparation of selected jobs so that they can be executed in an efficient manner during job execution that takes place in the future date (Smith & Hawkins, 2006:150). Planning is the process of detailed analysis to determine and describe the work to be performed, task sequence and methodology, plus identification of the required resources, including skills, crew size, labour-hours, spare parts and materials, special tools and equipment, including estimated total costs (Kirster & Hawkins, 2006:150). Kirster and Hawkins (2006:62) also highlight the following objectives of maintenance planning:

- optimal support of the operational production plan by improving maintenance in the broadest sense;
- completion of maintenance work when it is needed, in a safe and efficient manner and at the optimal cost;
- minimisation of lost production time due to maintenance;
- optimised utilisation of maintenance personnel and materials through effectively planned and balanced schedules;
- equitable resource allocation based on understood criteria and varying business needs and the internal customer support and
- minimisation of labour delays and idle time through effective coordination of all participating functions.

Kirster and Hawkins (2006:59) identify the following advantages of maintenance work planning:

- accurate workload measurement;
- accurate delivery promises;
- better methods and procedures to do the work;
- establishment of priorities;2
- monitoring of job status;
- coordinated trades, parts and materials;

- production equipment available when needed and
- bottlenecks and interruptions anticipated and avoided.

Planning is how to do the job, the development of a detailed programme to achieve an end and the advanced preparation of a specific job so it can be performed in an efficient and effective manner (Nyman & Levitt, 2010:XIII). According to Kelly, (2006:19) maintenance work control is a system that is needed to ensure that the maintenance organisation is achieving its objectives and to initiate corrective actions.

In closing, Kirster and Hawkins (2006:301), point out that control is the process by which comparisons are made between the plan and the actual performance, either during or after execution.

2.4.1.6 Safety, health and environment (SHE)

SHE is the structured process for managing the safety, health and environmental responsibilities of the organisation. This includes systems, policies and procedures for the development, communication, implementation, measurement and review of the SHE programme. The objective of implementing the SHE programme is to enable the enterprise to maintain a safe, healthy and environmentally friendly operation (Ross, 2005:8). Health is exposure to any substance, noise or other elements that cause temporary or permanent illness or impairment of any bodily function. Environment is any accidental or planned emission that pollutes the atmosphere, land or waterway in the vicinity of the plant and beyond (Lenahan, 2006:134).

According to Lenahan, (2006:135) management of safety is not an academic exercise but it is about real people and the effectiveness of the safety, health and environmental system. He further mentions that in the extreme cases people who entrust their lives to safety, health and environmental system live or die. Lenahan (2006:147) identifies the following rules concerning risks, hazards and accidents:

- the specific circumstances surrounding accidents are almost never repeated and

- the underlying causes of accidents are always the same and are any combination of the following:

    - un-educated, incompetent or uncaring management,
    - inadequate safety systems, standards and procedures,
    - bad planning and preparation,
    - inadequate safety awareness and
    - incorrect motivation.

2.4.2 Execution perspective

This section addresses the four dimensions of executing activities and work for improved performance, effectiveness and efficiency of assets. The dimensions are organisation and manpower, autonomous maintenance, contractor management and improvement culture. These dimensions are discussed in detail in the next sections.

2.4.2.1 Organisation and manpower

Most organisations have a significant amount of trouble justifying additional resources, even when the facility has gained more equipment, more square footage and higher production levels than when current staffing was established (Nyman *et al.,* 2001:47). Nyman *et al.* (2001:51) identify the following four invisible demands for staffing purposes:

- Catastrophic demand: supplying staff and resources for a blizzard or small fire (incident) or breakdown instead of planned and preventive maintenance;
- Construction-related demand: utilisation of skilled and experienced labour for construction projects instead of maintenance;
- Social demand: utilisation of maintenance resources (labour) for visitor plant walks instead of performing real maintenance work;
- Personal-service demand: utilisation of maintenance resources (labour) for driving and parcel pick-up instead of performing actual maintenance work.

One goal of the maintenance organisation should be the effective use of maintenance resources (Mobley, 2004:7), which is the structuring of the enterprise with competent staff to perform the required functions. Included is the organisational structure, the policies and procedures for job profiling, performance management, skills and competency development as well as rewards and incentives. It enables the enterprise to deploy the right number of maintenance staff with the required skills levels to perform maintenance tasks (Ross, 2005:9).

According to Kelly, (2006:4) organisations can be organised on the basis of their objectives into public and private enterprise. He further points out that according to Riddle (1994) organisations need to carry out the following two prime functions:

- First, the internal mechanisms of the industrial enterprise itself must be made to operate well. The right product must be made at the right time by the right plant, using the right materials and employing appropriate workforce. The physical assets must be carefully selected and properly maintained. Effective long-term research and development plans must be implemented and new capital investment generated. This implies that the internal efficiency must be very high.

- Second, interaction with the outside world, with external influences and constraints, must be made to be cooperative and beneficial rather than antagonistic and damaging. This implies that the overall externally measured efficiency must be very high.

Kelly (2006:6) further elaborates that according to Kast & Rosenzweig. (1974), an organisation is an open, socio-technical system with the following five sub-systems (Figure 2.4):

- a goal-oriented arrangement: organisations must employ people with a purpose;
- a technical sub-system: organisations must encourage people to use knowledge, techniques, equipment and facilities;
- a structured sub-system: organisations must ensure that people work together on integrated activities;
- a psycho-social sub-system: organisations must be aware that people in their employment live among societies and have relationships with their societies and

- a managerial sub-system: this sub-system is responsible for planning and controlling the overall endeavour that is to ensure that the activities of the organisation as a whole are directed towards the accomplishment of its objectives.

The Environmental System Organisation and Manpower

Figure 2.4 The Organisational System
(Source: Kelly, 2006:6, Figure 2)

2.4.2.2 Autonomous maintenance

As competition increases, companies need to become more competitive and autonomous maintenance is becoming a vital part of running an organisation at its peak effectiveness to eliminate loss and waste and maximise equipment effectiveness (Hughes, 2001:39). The author, further identifies the following main goals of autonomous maintenance:

- preventing deterioration through housekeeping and correct operation;
- measuring deterioration through daily inspections and
- correcting deterioration through minor servicing and accurate failure reporting.

Autonomous maintenance is the deployment of the philosophy whereby capable production staff take full ownership of the assets while in their care. It includes the systems, policies and procedures for daily checks, lubrication, replacement of parts, basic repairs, first-line maintenance, correct operation as well as a structured approach to teamwork. It enables the enterprise to prevent, detect and correct potential asset problems at an early stage (Ross, 2005:10).

2.4.2.3 Contractor management

Contractor management is the structured process and associated guidelines for the management of outsourced work. It includes the systems, policies and procedures for the selection, contracting and performance management of contracts. Contractor management enables the enterprise to optimise the effective utilisation of outsourced asset management tasks (Ross, 2005:10). Lenahan (2004:62) identifies the following five factors influencing the use of the contractor:

(1) resource availability: this pertains to critical skills, knowledge and expertise;
(2) experience: this pertains to contracts specialising in critical or complicated maintenance activities;
(3) professionalism: this pertains to the delivery of high quality service;
(4) specialism: this pertains to specialised, complex or hazardous work and
(5) productivity and cost: this is a belief that contractors provide higher productivity at lower costs to the organisation.

2.4.2.4 Improvement culture

Continuous improvement means negotiating goals, achieving those goals and then extending the goals (Hughes, 2001:156). Hughes (2001:156), further identifies the following features of continuous improvement:

- management views the performance level of the organisation as something to be continuously challenged and incrementally upgraded and
- management views the contribution and role of its workforce as extremely important.

2.4.3 Technical perspective

This section addresses the three dimensions of technical expertise required to execute activities and work successfully, effectively and efficiently. The dimensions are maintenance tactics, spares and materials and tools and workshops.

2.4.3.1 Maintenance tactics

Visser (2002:1) lists the following maintenance tactics:

- time-based maintenance (TBM), which is the replacement or cleaning performed at predetermined time or usage intervals;
- condition-based maintenance (CBM), which indicates the condition of the equipment and is measured continuously or periodically; replacement is performed when the condition is no longer acceptable;
- operate-to-failure (OTF): equipment is run until a failure takes place, after which a replacement is performed and
- fault-finding maintenance (FFM): periodic checks are performed to determine whether back-up equipment or protective equipment is still fully functional.

Maintenance tactics is the structured process of analysing and understanding failure modes and the application of the most appropriate maintenance tactics. It includes all available tactics, namely breakdown, scheduled, condition-based maintenance reduction as well as supporting tools and techniques. It enables the enterprise to optimise total costs by using the best combination of maintenance tactics (Ross, 2005:12).

2.4.3.2 Spares and materials

Hughes (2001:73) identifies the following characteristics of good spares management:

(1) ensure that all necessary spare parts are held as stock items with appropriate minimum and maximum levels and re-order levels;
(2) identify spare parts that are manufactured locally;
(3) ensure that parts are correctly binned and stored;
(4) ensure that parts are correctly described and catalogued for speedy retrieval when required and
(5) remove all redundant spare parts.

According to Mobley (2004:7) reduction in spares inventory should be a major objective of the maintenance organisation. It is a structured process to manage spares and materials and includes the systems, policies and procedures for ordering, tracking, and issuing stock holding, as well as the optimisation of the inventory management systems. The enterprises are enabled to provide all the necessary spares and materials for the execution of maintenance tasks (Ross, 2005:12). Slater (2013:40) lists the following six tips designed to improve spare parts management:

- Tip 1: develop clear spare part stocking criteria, what to stock and what not to stock
  - is the item obsolete or likely to be obsolete in 6 months' time?
  - can something else be used that is available in stock? (substitution);
  - can usage be planned within the supply lead time? (forecast);
  - when required, can the item be delivered by a vendor in an acceptable lead time? (quick and local delivery);
  - can the asset in service be repaired in an acceptable lead time? (repair rather than replace);
  - is the item being ordered for a project? (not stocked);

   - can the need for the item be eliminated? (engineering-out);
   - can someone else's stock be used? (sharing/pooling);
- Tip 2: provide clear guidance on how many parts to stock;
- Tip 3: accept that some stock outs are acceptable;
- Tip 4: review the holding of the critical spare parts;
- Tip 5: identify the cause of excess spare parts inventory
   - track the status of the item;
   - determine the rule whether to buy or repair;
   - let the accountants worry about the cost allocation and
- Tip 6: review storeroom security
   - items being taken out or picked out without being recorded;
   - items being placed into the store, either from a new delivery or via a return to store, without being recorded.

2.4.3.3 Tools and workshops

This is the process to establish and manage workshop facilities and tools. Included are systems, policies and procedures for the consideration of location, layout and safety aspects of the workshops and the condition, use and management of all tools and maintenance thereof. The enterprise provides a productive work environment and tools for the execution of maintenance tasks (Ross, 2005:13).

2.4.4 Financial perspective

This section addresses the two dimensions of financial management expertise required to ensure that maintenance activities are executed within the agreed maintenance budgets. The dimensions are financial management and acquisition and disposal of assets.

2.4.4.1 Financial management

According to Smith and Hawkins (2004:23), firm control of expenditures is essential to the success of any individual operation. The short-term control, however, must not be achieved to the detriment of the long-term success of the manufacturing and maintenance operations. Smith and Hawkins (2004:23) maintain that management requires reliable procedures and relevant records to determine the following:

(1) where and why have costs been incurred? (history);

(2) how essentially and effectively managed have costs been historically?

(3) the cost control effectiveness of each function;

(4) how effectively has the application of authorised resources supported the broad organisational vision and mission?

(5) what changes are anticipated that will influence future resources needs and how significant will that influence be?

(6) discretionary budget items that can be released or deleted as conditions throughout the budgetary period dictate;

(7) appropriate budgets reflective of the above considerations;

(8) how actual costs compare to budgeted costs;

(9) periodic results and progress and

(10) obstacles to the control process.

2.4.4.2 Asset acquisition and disposal

This is a structured process for the acquisition and disposal of assets. Included are systems, policies and procedures for the conceptualisation, design, acquisition, commissioning and disposal of assets. This enables the enterprise to optimise the life cycle cost of its assets (Ross, 2005:14). Kelly (2006:11) identifies the following three factors affecting the application of life-cycle cost analysis:

- first, the lack of definition of the asset acquisition sub-system;
- second, the complex relationships between the many factors involved in the economic compromise and
- third, the uncertainty of much of the life-cycle information.

2.4.5 Asset management challenges

The following are the enablers for good asset management, as per PAS 55-2 (2008:VII):

- first, an organisational structure that facilitates the implementation of asset management principles with clear direction and leadership;
- second, staff awareness, competency, commitment and cross-functional coordination and

- last, an adequate information and knowledge of asset condition, performance, risks and costs, and the interrelationships between these.

In order to achieve its organisational strategic plan and provide the assurance to stakeholders, an organisation needs to ask and be able to answer the following key asset management challenge questions:

- Does the organisation know what existing assets it owns, where they are, what condition they are in, what function they perform and their contribution to value?
- Does leadership know what they want from their assets in the short, medium and long-term?
- Can the assets deliver asset management objectives cost effectively?
- Is the organisation getting the most value from its assets and how could it get more value for money from assets?
- Is the capacity enough, have some assets or systems become redundant, under-utilised, unprofitable or too expensive, insufficient, or too excessive?
- Is the risk of assets causing harm to people and environment?
- Is asset-related expenditure (capital investment and operating costs) insufficient, excessive or optimal and correctly assigned across the asset portfolio?
- Can the benefit (performance, risk reduction, compliance and sustainability) of proposed work or investment be evaluated or quantified?
- Is leadership allowing future problems to develop (such as performance deterioration, risks, expenditure requirements) in the effort to obtain short-term gains?
- Is the appropriateness of asset management strategy reviewed in the light of changes in the operating, regulatory and financial aspects?
- Is the organisation continually improving asset management system performance and realising the benefits of the improvements?
- Does the organisation have the necessary asset management policy, strategy and plan to ensure that assets are managed in a suitable way?

- Are the working conditions, skills, knowledge, competency and wellbeing of employees and contracted service providers given appropriate consideration? (PAS 55-2, 2008:viii)

2.5 MAINTENANCE

According to Coetzee (1997:23), maintenance is critical, crucial and needed for the following reasons:

- the increased sophistication of high production equipment;
- the need for a high return on investment;
- the high cost of maintenance and
- the complexity of the maintenance function.

It is the task of the maintenance function to support the production process with adequate levels of availability, reliability and operability at an acceptable cost (Coetzee, 1997:24).

The need for maintenance originates at component level, when it is unable, according to some pre-determined criterion, to perform its designated function. It can then be said to have failed (complete or partial loss of function). Most organisations search continually for any means, programme, process, concept or approach by which to improve their maintenance function. They strive to ensure that each maintenance dollar is well spent (labour productivity) while achieving equipment reliability (asset productivity) (Nyman *et al.,* 2001:IX). According to Nyman *et al.* (2001:XI), maintenance is a resource that contributes to the achievement of profit objectives.

Smith and Hawkins (2004:32) identify the following as core maintenance objectives:

- to control maintenance workload (backlog management, adherence to daily schedules);
- to continually reduce equipment downtime and increase availability through the establishment of preventive maintenance programmes;

- to ensure that work is performed efficiently through organised planning, optimised material support and coordinated work execution;
- to establish maintenance processes, procedures and best practices to achieve optimal response to emergency and urgent conditions;
- to create and maintain measurements of maintenance performance and
- to provide meaningful management reports to enhance control of maintenance operations.

Peters (2006:16) identifies the following twenty-four key requirements for profit and customer centred maintenance:

- view maintenance as a priority and as an internal business opportunity;
- develop leadership and technical understanding (skills, abilities and attitude);
- form a partnership between maintenance and engineering for profitable technology application;
- continuously improve reliability and maintainability;
- manage life-cycle cost and obsolescence;
- minimise uncertainty and eliminate root-cause;
- maximise use of computerised maintenance management system (cmms) and enterprise asset management (eam);
- use maintenance information to manage the business of maintenance;
- ensure an effective maintenance storeroom operation;
- establish the spare parts inventory as the cornerstone for effective maintenance;
- establish a safe and productive working environment;
- aggressively support compliance with environmental, health and safety requirements;
- continuously evaluate, measure and improve maintenance performance and service;
- develop pride in maintenance (work ethnics, attitude, values, job performance and customer service);
- recognise the importance of the maintenance profession;

- increase core competencies of maintenance personnel (training, coaching and development);
- initiate craft skills development to enhance people resources (competency based development, assessment);
- develop adaptability and versatility (flexibility, multi-skilled, capability);
- promote teamwork as a profit and customer-centred strategy;
- establish effective maintenance planning, estimating and scheduling;
- form maintenance and manufacturing operations into a partnership for profits;
- develop pride in ownership (operator-based maintenance);
- improve equipment effectiveness and
- benchmark where you are and improve maintenance in total, not piecemeal.

2.5.1 The Maintenance Cycle

The maintenance cycle consists of two super-imposed cycles, the outer cycle representing the managerial sub-cycle (Figure 2.5: The managerial sub-cycle) and the inner cycle, representing the operational technical processes (Figure 2.7: The operational sub-cycle).

2.5.1.1 The managerial sub-cycle

The managerial sub-cycle comprises maintenance policy, objectives, management planning and maintenance auditing (Coetzee, 1997:38).

(a) Maintenance policy

The maintenance policy describes, in broad terms, the direction in which the maintenance management team wants to steer the maintenance organisation (Coetzee, 1997:38). Maintenance policy is a statement of principle used to guide maintenance management decision making. This may be more detailed to include storeroom operation procedures, planning and scheduling procedures, purchasing procedures and training (Peters, 2006:497).

(b) Objectives

The objectives should be developed by first doing an analysis of how well the maintenance organisation is already performing in terms of the management team's direction, as set in the policy document (Coetzee, 1997:39). Objectives describe a desired state of organisational being. Objectives are the accomplishments sought by an organisation over a long period of time (Smith & Hawkins, 2004:20). Maintenance operation objectives must support both the plant's strategic and production plans. Objectives must be consistent with the mission statement (Smith & Hawkins, 2004:32). The primary goal of a maintenance operation is to provide equipment efficiency. The secondary goal is to deliver equipment efficiency as cost effectively as possible (Mobley, 2004:379). According to Kelly (2006:68), the objectives might be considered as being to achieve the optimum balance between the allocation of maintenance resources and achievement of the plant output.

The Objective Model

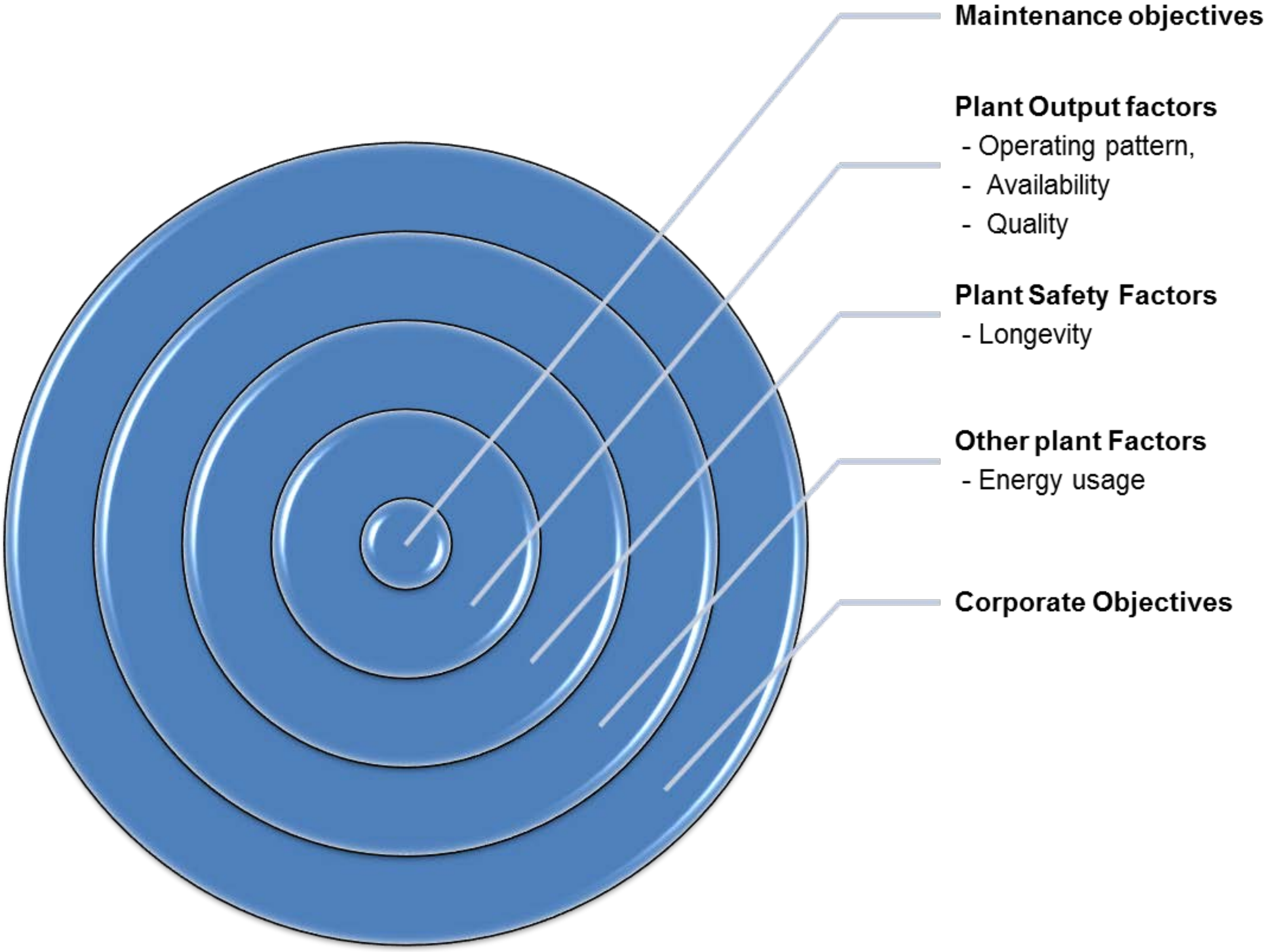

Figure 2.5 Factors influencing maintenance objectives setting
(Source: Kelly, 2006:68)

(c) Management planning

According to Coetzee (1997:39), management planning is the strategic (long-term) planning process performed by the top leadership of an organisation. It addresses the following aspects:

- The maintenance organisation: the type of organisational structure to be used and why, how and when to change;
- Manpower: strength and types;
- Resources: what and how much (tools, materials);
- Facility improvement plans;
- How maintenance will be financed (running budget, special classes of accounts);
- The budget itself, with all its different categories.

(d) Maintenance audit

This is a formal assessment of the department, which is carried out yearly. The assessment includes hard and soft audits, of which 'hard' audit refers to physical inspections and scoring and 'soft' audit assesses the management and technical systems (Coetzee, 1997:39).

The Managerial Sub-Cycle

Figure 2.6 The Managerial Sub-Cycle
(Source: Coetzee, 1997:38)

2.5.1.2 The operational sub-cycle

The operational sub-cycle consists of the maintenance strategy, maintenance plans, maintenance administration, task execution, task management, task feedback, cost results, performance results, maintenance history and strategy optimisation (Coetzee, 1997:41).

(a) The maintenance strategy

This is a decision made on selected maintenance approaches or tactics, such as run to failure, design-out, preventive, condition based (Coetzee, 1997:41). According to Mobley (2004:8), there are three types of maintenance strategies and these are listed as:

- Maintenance improvement: reduces or eliminates the need for maintenance.
- Corrective maintenance: this is emergent work, repair work, remedial work and/or unscheduled work.
- Preventive maintenance: is classified into reactive maintenance, condition monitoring and scheduled maintenance.

According to Peters, (2006:498) maintenance strategy is a set of principles and strategies for guiding decisions for maintenance management: a long-term plan covering all aspects of maintenance management, which sets the direction for maintenance management and contains firm action plans for achieving a desired future state for the maintenance function. Atkinson (2012:8) identifies the following production asset maintenance strategies:

(1) reactive or breakdown maintenance: run until it breaks down;
(2) routine (planned/preventive) maintenance;
(3) condition based (predictive) maintenance and
(4) proactive maintenance.

He further highlights the following advantages and disadvantages of routine (planned/preventive) maintenance and condition-based (predictive) maintenance.

Disadvantages of routine (planned and preventive) maintenance

- A lot of effort is needlessly wasted on machines that are in working order.
- Scheduling is often difficult to get right and relies on luck that machines do not randomly breakdown.
- Spares have to be ordered after the machine is stripped down or expensive redundant stock has to be carried.
- Stripping down machines sometimes actually introduces faults.
- Can be very expensive if one gets it wrong.

Advantages of condition based (predictive) maintenance

- No wasted effort, only machines that need fixing are repaired.
- Things are spotted before they break.
- Work can be planned to coincide with shutdowns.
- Spares can be ordered in advance before machine breakdown.
- Reduced downtime.

According to Myburg (2009:11), the maintenance strategy is a specification of the 'types' of maintenance, which are to be done to specific equipment type, at a specific rate or frequency, under specific operating conditions as per Figure 2.7 below:

The Maintenance Strategy Model

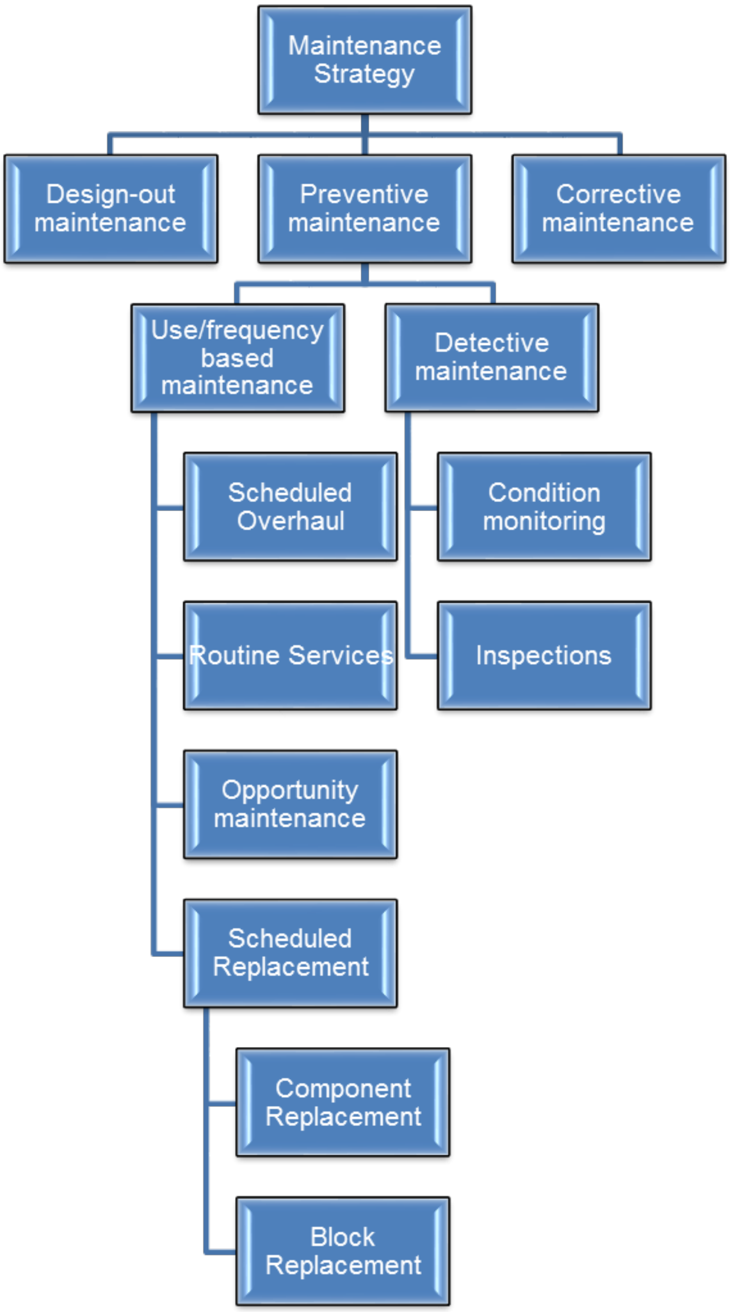

Figure 2.7 The Maintenance Strategy Model
(Source: Myburg, 2009:11)

(b) Maintenance plans

Maintenance plans are electronic or hard copy documents of the complete RCM and maintenance tasks that should be scheduled for performance at predefined intervals (Coetzee, 1997:42). Maintenance plans contain information very similar to that in a work order. These are work plans that are associated with equipment or asset records and that are usually created automatically by the CMMS, as determined by their execution frequency (Cato & Mobley, 2002:27).

(c) Maintenance administration

Maintenance administration is the function traditionally known as maintenance planning and scheduling, involving all aspects of task scheduling, task planning, procurement, issue of task documentation and feedback of task data (Coetzee, 1997:42). According to Kirster and Hawkins (2006:118), maintenance administration:

- is the advance preparation of selected jobs so that they can be executed in an efficient manner when the job is performed at some future date;
- is a process of detailed analysis to first determine and then to describe the work to be performed by task sequence and methodology;
- provides for the identification of all required resources including skills, crew size, labour-hours, spare parts and materials, special tools and equipment and
- includes developing an estimate of total cost and encompasses essential preparatory, post maintenance and restart effort of both operations and maintenance.

Kirster and Hawkins (2006:119) identify the following principles for maintenance administration (planning and scheduling):

- Understand the department's mission in relation to the objectives of the company.
- Always be aware of the magnitude and trend of backlog.
- Quantify the magnitude of the resources effectively available to apply towards relief of the backlog.
- Establish a plan for the allocation of available resources to a balanced work week considering both long-range importance and short-range necessity.

- Categorise work consistent with planned resource allocation categories.
- Assign a planning priority with job priority and category to each job.
- Break each job into logically sequenced tasks and activities.
- Prepare a planning week schedule by phases of work planning and by task to determine progress towards completion of each week's work planning.
- Work to meet this schedule, protect it and do not superimpose new work unless that new work represents an overriding course of action for work planning (short-range and long-range).

Kirster and Hawkins (2006:194) point out that maintenance schedules as part of maintenance administration represent the following:

- The best utilisation of personnel who can be predicted for the work that has to be done.
- A statement of priorities mutually accepted to maintenance and operations.
- A means of communication for coordinating maintenance commitments between trades and with operations.
- A definition of the maintenance supervisor's responsibilities.
- A means of controlling time spent on each work order.
- A working plan from which the maintenance supervisor can assign personnel and on which they can indicate schedule interruptions.
- A means of keeping maintenance and operations fully aware of what is happening, so that they can actively participate in establishing and adjusting priorities.

Kirster and Hawkins (2006:195) identify the following pre-requisites for effective scheduling as part of maintenance administration:

- Lead time: essential work must be identified in advance and be planned and scheduled effectively.
- Backlog: must be kept within a reasonable range.
- Special demands: cannot be scheduled unless backlog is addressed.

- Jobs will not be scheduled until all planned needs (materials, parts, tools, special equipment) are available in the quantities required and that time is available.
- Each available maintenance trade must be scheduled for a full day of productive work for every day of availability.
- Emergency work may be done at the expense of scheduled jobs if additional resources are required to augment the emergency work group.

In closing, Kirster and Hawkins (2006:196) maintain that adherence to the above pre-requisites will ensure that the following is achieved:

- All maintenance needs are properly attended to.
- Accurate evaluations are made as to the importance of each job with respect to the operation as a whole.
- Customers will have their work performed on time.
- Equipment downtimes will experience minimum delays.
- Work is performed safely and
- Overall maintenance cost is kept to a minimum.

(d) Task execution

Task execution is a process during which the maintenance worker performs the work as specified in their task documents (Coetzee, 1997:42). According to Kirster and Hawkins (2006:33), there are three principal types of maintenance execution demands and these are listed as follows:

- the routine or preventive maintenance demand, which is the performance of all management approved routine tasks in accordance with detailed schedules and established quality levels: this work is classified as specifically defined, performed according to a known schedule, performed in a planned pattern and involves a consistent work content and requires a predictable amount of time;
- the emergency demand, which is the handling of emergency demands;
- the planned maintenance demand, which represents all work other than emergency and routine.

(e) Task management

Task management is the supervisory process whereby the task is controlled. It includes the task areas, such as quality control, expert advice to workers, task follow-up, requisitioning, prioritising, backlog management, budget control, safety and housekeeping and facility management (Coetzee, 1997:42). The purpose of measuring performance is to help predict future actions and performance based on historical data. Measuring performance helps in identifying areas that need management attention and highlights successful areas and accomplishments (Mobley, 2004:374). According to Mobley, (2004:374) measurements must be reviewed on a regular basis to provide insights into the following performance measurement or task management best practices philosophical guidelines:

(1) one cannot measure everything;
(2) performance management is like a garage to equipment, it tells operating condition;
(3) manage what one can measure;
(4) turn data into information, then into action;
(5) indicators must tie into a 'strategic business plan' and have purpose;
(6) downplay only external comparison, that is, external benchmarking data collected, analysed and shared;
(7) review performance information regularly, at least every quarter;
(8) present performance information on a chart or graph;
(9) trend performance information and provide explanations.

(f) Task feedback

The time and cost required for every work order should be reported and analysed to provide guidance for more accurate planning in future (Mobley, 2004:39). Reporting systems should be in place for every maintenance organisation, regardless of size or whether or not a CMMS is implemented. Feedback should provide assistance to the organisation in determining whether goals and/or objectives are being met, if the organisation is satisfying customer needs and if it is operating efficiently and economically (Mobley, 2004:375). Peters (2006:171) lists the following six requirements for CMMS data integrity:

- equipment (asset) history data complete and accuracy must be 95% or higher;
- spare parts inventory master record accuracy must be 95% or higher;
- bill of materials (BOM) for critical equipment includes listing of critical spare parts;
- preventive maintenance tasks and frequency data complete for applicable assets must be 95% or higher;
- direct responsibilities for maintaining parts inventory database are assigned and
- direct responsibilities for maintaining equipment or asset database is assigned.

(g) Cost results

Peters (2006:177) lists the following factors for maximising information technology investment with the CMMS benchmarking system for budgeting and cost control:

- craft labour, parts and vendor support costs are charged to work order and are accounted for in equipment or asset history file;
- budget status on maintenance expenditures by operating departments is available;
- cost improvements due to CMMS and best practice implemented have been documented;
- deferred maintenance and repairs are identified to management during budgeting process and
- life cycle costing is supported by monitoring of repair costs to replacement value.

(h) Performance results

Smith and Hawkins (2004:41) list the following rules for applying performance indicators for effective results:

- good metrics focus activities on maximum benefits and value added;
- poor metrics lead away from optimum activity often to unintended results;
- whenever possible, metrics should be positive rather than negative;
- avoid conflicting metrics;
- always examine complementary metrics together;
- non-compliance with a metric should be followed by efforts to identify the cause, full cost and other effects of non-compliance and

- metrics must be used and kept current, metrics that are not regularly used must be eliminated.

In closing, Smith and Hawkins (2004:42) report that the more commonly used maintenance metrics or performance indicators can be classified into the following three categories:

Category 1: Metrics of equipment performances on availability (Av), reliability (Rv) and overall equipment efficiency (OEE);

Category 2: Metrics of cost performances on, for example, labour, materials;

Category 3: Metrics of process performance on planned and unplanned work, schedule compliance, for example.

(i) Maintenance history

Work order or equipment/asset history provides the basis for analysing how well the maintenance organisation is meeting its goals. When the work order is closed, it is automatically stored on a history file. Maintenance history is the combination of skill, craft-hours, expended materials used and what has been done to repair or fix the failure (Cato & Mobley, 2002:28). The last function of the work order control system is to document the work that was actually performed during execution, labour and materials are charged to the work order through the time entry and stores system, work performed, components affected, condition of components and cause of failure are key elements for the accumulation of equipment maintenance history from work order. They provide valuable information (history) for conducting failure analysis (Kirster and Hawkins 2006:142).

According to Kirster and Hawkins (2006:178), the meaningful and readily usable and retrieval equipment history is dependent upon a thorough, intelligent and consistently utilised equipment numbering system. Equipment history systems that are properly designed and effectively administered facilitate the following:

- identification of equipment requiring abnormally high levels of maintenance;
- analysis of maintenance history for high maintenance equipment to identify specific repetitive failures to which value engineering discipline should be

applied to determine how equipment or instrumentation might be modified to reduce premature equipment failures, frequency of repetitive failures and the general level of required maintenance;

- comparison of equipment maintenance cost with replacement cost as a tool in capital planning and
- the justification and refinement of the preventive maintenance programme.

In closing, Kirster and Hawkins *(*2006:180) identify the following requirements (what) and value/benefits (why) of the equipment history:

(1) equipment history is a foundation element of maintenance management: it is a primary tool of reliability engineering;
(2) identification of equipment requiring abnormally high levels of maintenance;
(3) analysis to identify specific repetitive failures;
(4) comparison of maintenance cost with replacement costs;
(5) justification and refinement of the preventive maintenance programme;
(6) to evaluate maintenance failure trends in order to direct corrective action, reliability engineers need a reliable, meaningful and detailed history of repairs and
(7) history also supports the informational needs of engineering, operations, accounting and other members of maintenance.

Lastly, Kirster and Hawkins (2006:181) identify the following seven essential elements for effective equipment history:

- an effective equipment numbering system, that is, installed location and specific equipment unit;
- a well-designed and administered work order system;
- effective cost distribution to work orders, that is, labour, materials, contractors, for example;
- accurate downtime reporting;
- meaningful and consistent work descriptions;
- ease of information retrieval and

- reliability engineering to make effective use of the information base.

(j) Strategy optimisation

Strategy optimisation is the utilisation of maintenance techniques like RCM to check, assess and improve frequencies, task descriptions and equipment data information (Coetzee, 1997:42).

The Operational Sub-Cycle

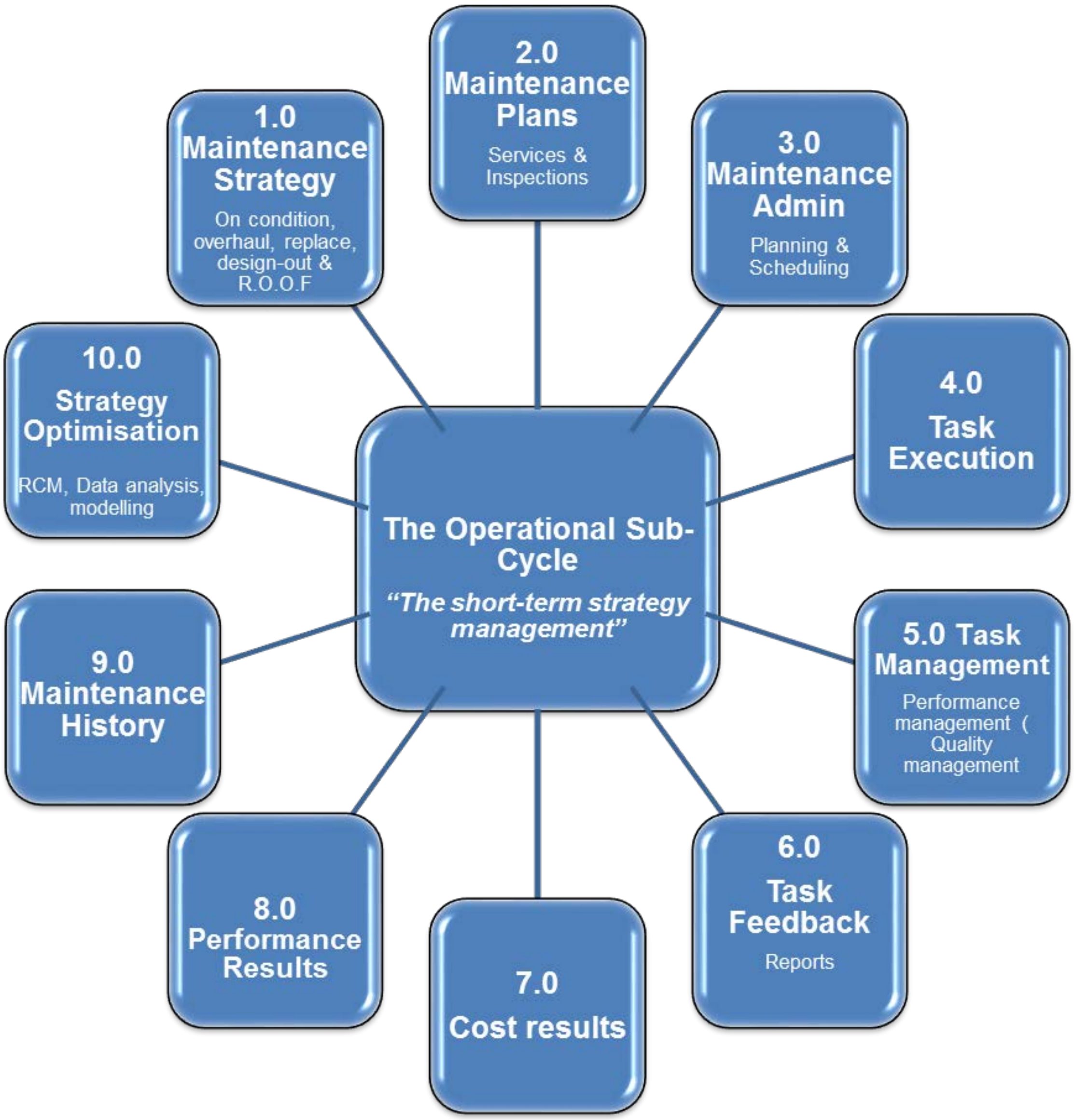

Figure 2.8 The Operational Sub-Cycle
(Source: Coetzee, 1997:41)

2.5.2 Challenges of maintenance

According to Peters (2006:29), there are four real challenges in maintenance and he lists them as follows (Figure 2.9):

(1) Challenge one: maintaining existing production assets, equipment and facilities in a safe and sound condition;

(2) Challenge two: improving, enhancing and then maintaining existing assets and facilities to achieve environmental or regulatory standards, greater production capacity at better quality, while using the best energy practices;

(3) Challenge three: enhancing, renovating and modifying/overhauling existing assets or facilities using capital funds or funds from tenants/customers and then maintaining the new additions or enhancements;

(4) Challenge four: commissioning new production assets or facilities; assume increased scope of work to maintain the new assets.

The Maintenance Challenges Model

Figure 2.9 The Maintenance Challenges Model
(Source: Peters, 2006:31)

2.5.3 Maintenance best practices

First, the best maintenance practices are the established standards for the performance of industrial maintenance. Second, measuring plant existing maintenance process using the yardstick of the best maintenance processes can reveal both the degree of permit identification of the specific maintenance processes causing variations in equipment reliability. Third, the best maintenance practices are samples established by John Day, former engineering manager at Alumax, which has been acknowledged worldwide for over twenty years as the best in maintenance through achievement of recognition as a world class operation (Smith & Hawkins*,* 2004:68). Lastly, Smith and Hawkins (2004:68) identify the following practical and effective approach to determine the need for, and implementation of, the best maintenance practices (refer to Table 2.1):

- Identify whether an equipment reliability problem exists and whether it impacts quality and then determine the magnitude in monetary value.
- Perform a maintenance assessment to identify where the variations are in the maintenance process.
- Develop an action plan and timelines, together with benchmarks and performance matrices to reduce variations in the maintenance process.
- As measurements are done, implementation and improvements to the maintenance process are necessary.

According to Peters (2006:XXV) the best maintenance practices identified for today's global competitiveness are in areas such as:

- preventive/predictive maintenance,
- continuous reliability improvement,
- reliability centred maintenance (RCM),
- maintenance parts and materials control,
- maintenance storeroom operations,
- work order and work control,
- maintenance planning and scheduling,
- maintenance budgeting and cost control,
- operator based continuous improvements,
- improving and measuring equipment effectiveness and reliability,
- craft skills development,
- maintenance performance measurement,

- computerised maintenance management system (CMMS) and
- continuous maintenance improvement.

Table 2.1 The Best Maintenance Practice

Measurement standard	Possible causes	Solutions
No self-induced equipment failures (NB: 70% of equipment failures in industry today are self-induced)	Lack of skilled workforce	Skills assessment and training
	Operator errors	TPM or operator procedures
	Reactive culture	Change measurements
	Preventive maintenance procedures not performed properly	Preventive maintenance must be managed as an experiment
30% of all labour hours should be on preventive maintenance	Preventive maintenance not being performed to a standard	Have detailed procedures
	Preventive maintenance inspections not a high priority	Measure preventive maintenance compliance
90% of all work orders come from preventive maintenance	Preventive maintenance inspections are turning into repair activities	Train personnel in proper preventive maintenance execution
	90% of all maintenance work is not planned and scheduled	Implement a true planned/scheduled maintenance programme
Emergency work is less than 2% of total maintenance labour hours	No preventive maintenance compliance	Preventive maintenance schedules must be completed within 10% of the frequency. Preventive maintenance compliance to within 3 days plus or minus.

(Source: Smith and Hawkins, 2004:69, courtesy of John Day)

2.6 CHAPTER SUMMARY

This chapter provided an overview of the asset management framework and the maintenance cycle. It also highlighted the status of asset management and maintenance in developed and developing countries, including South Africa. The next section of this chapter briefly detailed the asset management, asset management framework and asset management challenges. A detailed discussion on maintenance followed with the emphasis on the maintenance cycle (the managerial and the operational sub-cycles) and lastly the challenges of maintenance and maintenance best practices were also outlined and introduced.

Chapter 3 will introduce and discuss Maintenance Management Systems (MMSs) as one of the constructs that forms part of the main purpose of this study. The MS will also be reviewed as a means to assess the impact of the MMS and the status or level of maintenance at PetroSA GTL Refinery.

Chapter 3: MAINTENANCE MANAGEMENT SYSTEMS (MMSS)

3.1 INTRODUCTION

The previous chapter provided an overview of the asset management framework, asset management challenges, maintenance, the maintenance cycle, challenges of maintenance and the best maintenance practices.

The purpose of this chapter is to gain insight into various types of maintenance management system and their role and/or significance for asset management, maintenance and production output. The chapter continues to identify different types of MMS and offers a detailed description of the MS assessment tool. The use of this assessment tool is also justified.

The main sections of this chapter are outlined in Figure 3.1 below.

CHAPTER 3: MAINTENANCE MANAGEMENT SYSTEMS (MMS's)

3.1 INTRODUCTION

3.2 DEFINITIONS OF MMS

3.3 TYPES OF MMSs

3.3.1 Total Productive Maintenance (TPM)
3.3.2 Reliability Centred Maintenance (RCM)
3.3.3 Computerised Maintenance Management System (CMMS)
3.3.4 Business Centred Maintenance (BCM)
3.3.5 Risk Based Inspection (RBI)

3.4 DIMENSIONS OF MMS

3.4.1 Organisational Structure and Size
3.4.2 Computer Information and Support
3.4.3 Maintenance Work Measurement
3.4.4 Material Support and Control
3.4.5 Maintenance Planning, Work Scheduling and Coordination

3.5 MAINTENANCE SCORECARD (MS)

3.5.1 The History of MS
3.5.2 The MS Tool
3.5.3 Criticism of MS Tool
3.5.4 The MMS Gaps
3.5.5 Application of MS Tool

3.6 CHAPTER SUMMARY

Figure 3.1 Layout of Chapter 3

3.2 DEFINITIONS OF MMS

It is evident from literature that there are plenty of definitions of maintenance management systems; some of the definitions were presented in Chapter 1. This section will briefly expand on additional definitions of maintenance management systems which have been proposed by several authors.

Myburg (2009:3) reports that various sub-systems of physical asset management have matured and became well entrenched, particularly reliability centred maintenance (RCM), total productive maintenance (TPM) and total quality management (TQM). Berger (2010:13) lists TPM, RCM and lean maintenance (LM) as improvement systems relevant to maintenance in support of operators. Myburg (2011:2) indicates that the publicly available standard (PAS 55) is gaining ground as a standard of choice for management of physical assets. He further elaborates that PAS 55 does not define an 'ideal' asset management system, but rather provides a set of minimum requirements to which the asset management system should conform. Harris (2011:33) reports that asset management has developed and philosophies like total productive maintenance (TPM), risk-based inspection and maintenance (RBIM), business-centred maintenance (BCM), value driven maintenance (VDM) and lean maintenance (LM) systems are currently utilised. Clarke and Young (2011:34) argue that reliability centred maintenance (RCM) is the leading developed MMS.

Saltzer (2012:10) maintains that value-adding methodologies such as value driven maintenance (VDM) have been adopted by some of the world’s leading organisations in the manufacturing, transportation, utility and energy sectors to create significant economic value. He adds that this is also achieved by deploying the correct, key performance indicator tools to gather real intelligence on the performance of their assets. Tyne (2012:14) reports that reliability centred maintenance (RCM) is the maintenance approach or system that identifies likely and dominant failure modes. He further elaborates that RCM is a systematic approach that focuses on preserving the asset. In addition, he contends that RCM addresses only failures that matter, using logical processes for making maintenance decisions. McCarthy (2012:8-12) points out that TPM is a tool or system that enhances continuous improvement. He further highlights that lean maintenance and TPM are tools and systems to systematically release the potential of the factory, the industry or the organisation.

3.3 TYPES OF MSS

This section addresses, explains and explores various types of maintenance management system. It also highlights the benefits of MMS as a business principle. Five types of MMS are described, namely, Total Productive Maintenance (TPM), Reliability Centred Maintenance (RCM), Computerised Maintenance Management System (CMMS), Business Centred Maintenance (BCM) and Risk Based Inspection (RBI).

3.3.1 Total productive maintenance (TPM)

TPM is an initiative for optimising the reliability and effectiveness of manufacturing equipment. It is based on teamwork and involves all levels in an organisation. This is the system designed to eliminate accidents, defects and breakdowns and prevent losses (Smith & Hawkins, 2004:55). According to Smith and Hawkins (2004:55), TPM is not a short-lived, problem-solving and maintenance cost reduction programme, but it is a process that changes corporate culture and permanently improves and maintains the overall effectiveness of equipment through the active involvement of all levels of employee in the organisation. Smith and Hawkins (2004:56) maintain that TPM cannot be applied to unreliable equipment; the organisation must initially bear the additional expense of restoring equipment to its proper condition and the education of personnel about the equipment.

According to Smith and Hawkins (2004:56), TPM addresses the major eleven losses namely:

(a) Planned shutdown losses
- this applies to no production, breaks, shift changes and planned maintenance;

(b) Downtime losses
- this applies to equipment failure or breakdown, setups and change-over, tooling or part changes and start-ups and adjustments;

(c) Performance efficiency losses

- these are the minor stops (less than six minutes) and reduced speed or cycle time;

(d) Quality losses

- this applies to scrap product or output, defects or rework and yield or process transition losses.

Smith and Hawkins (2004:68) point out that companies that want to compete more effectively in today's marketplace must be progressive in accepting the need for and the implementation of, change and the elimination of variations to improve equipment reliability and product quality in order to increase market share, revenue and profit. Smith and Hawkins (2004:70) claim that world-class benchmarking suggests that a proactive TPM organisation that adopts the principles of maintenance excellence will spend approximately 2% of estimated replacement value annually in maintenance labour, sub-contractors, spare parts and materials and overheads on site. As business moves towards a proactive TPM culture with more planned and scheduled work, the need for maintenance is identified early enough to be able to order materials and receive them in a just-in-time (JIT) scenario before failure occurs. TPM improves the organisation of spare parts storage, eliminates duplication of inventory and enables identification of obsolete inventory (Smith & Hawkins, 2004:74).

According to Kirster and Hawkins (2006:95), TPM is a company-wide equipment maintenance system that involves all employees from top-level management to production line workers and the building custodians. Kirster and Hawkins (2006:96) point out that TPM is built around the following six points:

(1) activities that must optimise overall equipment effectiveness (OEE);

(2) elimination of breakdown through a thorough system of maintenance throughout the equipment's entire life span;

(3) autonomous operator maintenance that:

- uses lower-skilled personnel to perform routine jobs that do not require skilled trades persons;
- uses operators to perform routine maintenance tasks on their equipment;

- uses operators to assist technicians in the repair of equipment when it is down;
- uses computerised technology to enable operators to calibrate selected instrumentation;
- uses technicians to assist operators during shutting down and starting up the plant;
- company is directed and motivated, yet works with autonomous small group activities and small group goals to coincide with company goals and
- implements day-to-day maintenance activities involving the total workforce (engineering, operations, maintenance management and customers);

(4) continuous training

- this refers to formal training, on the job-training, one point lesson and team members train each other.

Kirster and Hawkins (2006:97) agree and support the statement made by Smith and Hawkins (2004:56) above, that TPM works towards elimination of the six formidable obstacles to equipment effectiveness and identifies these obstacles as:

(1) downtime

- this is equipment failure from breakdowns, setup and adjustments;

(2) speed losses

- this applies to idling and minor stoppages due to abnormal operations of sensors, blockages of clutches, reduced speed due to discrepancies between designed and actual speed of equipment;

(3) defects

- this implies to process defects like scrap, downgrades, rejects and returns and reduced yields from all resources (such as raw materials, packaging, energy and labour).

In closing, Kirster and Hawkins (2006:97) maintain that TPM is not simply a short-lived problem solving or maintenance cost reduction programme. It is a process that changes corporate culture and permanently improves and maintains the overall effectiveness of equipment through the active involvement of operators and all other members of the organisation.

Berger (2010:14) highlights that TPM strives to achieve zero failures, zero defects, zero injuries and zero pollution. TPM programmes are preventive maintenance, autonomous maintenance and equipment upgrading (Grutter, 2010:276).

TPM is the productive maintenance carried out by all employees through small group activities (Pycraft, Singh, Phihlela, Slack, Chambers & Johnston, 2010:594). The authors identify the following five goals of TPM and the goals are to:

(1) improve equipment effectiveness by examining all the losses which occur;
(2) achieve autonomous maintenance by allowing staff to take responsibility for some of the maintenance tasks and for the improvement of maintenance performance;
(3) plan maintenance with a fully worked-out approach to all maintenance activities;
(4) train all staff in relevant maintenance skills, so that both maintenance and operating staff have all the skills to carry out their roles and
(5) achieve early equipment management by maintenance prevention which involves considering failure causes and the maintainability of equipment during its design, manufacture, installation and commissioning.

Davis (2010:18) identifies the following 5 pillars of TPM detailed in Figure 3.2 below:

- maximise overall equipment effectiveness (OEE);
- establish a thorough system of preventive maintenance (PM) for equipment's entire life span;
- implement TPM by involving all departments (that is, engineering, operations, maintenance and finance);
- involve every single employee, from top management to workers on the shop floor and
- promote TPM through motivation management (autonomous small group activities – SGA).

The Five Pillars of TPM

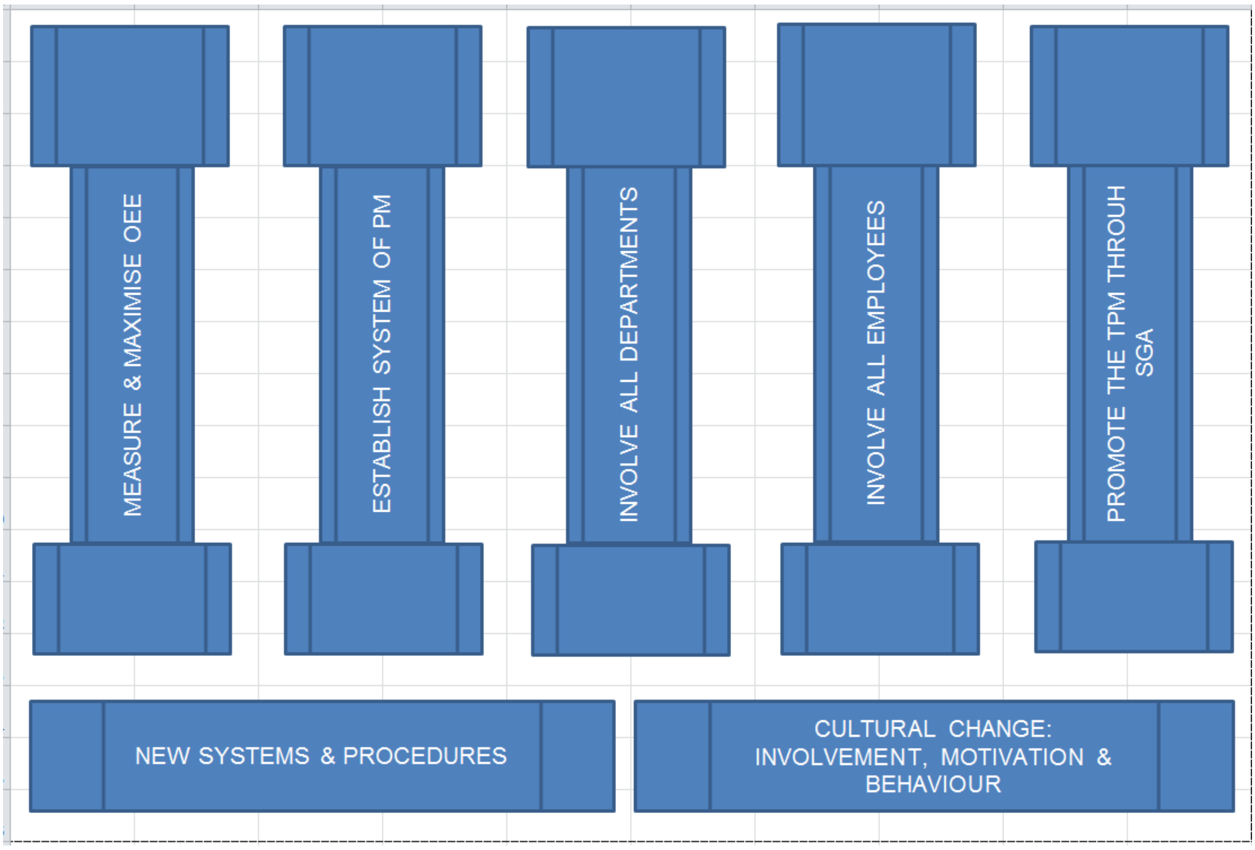

Figure 3.2 The Five Pillars of TPM
(Source, Davis: 2010:18)

3.3.2 Reliability centred maintenance (RCM)

RCM is a logical discipline to realise the inherent safety and reliability levels of complex equipment at minimum cost. RCM was published in the late 1970s; the publication was a milestone in the field of maintenance engineering. RCM provides the engineer with the necessary tools to determine what should be maintained, why it should be maintained and how it should be maintained (Hughes, 2001:12). Hughes (2001:12) further identifies the following objectives for implementing and maintaining the RCM system. These objectives are to:

- ensure realisation of the inherent safety and reliability of the equipment;
- restore the equipment to inherent levels of safety and reliability;

- identify and improve those systems or components whose reliability is sub-standard and
- accomplish goals at a minimum total cost, including maintenance costs and consequential failure costs.

RCM is a process of determining the maintenance requirements of physical assets in their present operating context. It is a continuous process used to determine the most effective approach to maintenance in support of this mission. It identifies the optimum mix of applicable and effective maintenance tasks needed to realise the inherent design reliability and safety of systems, equipment and personnel at minimal cost (Smith & Hawkins, 2004:92). Smith and Hawkins (2004:94) and Kirster and Hawkins (2006:99) highlight the following seven questions that form the basis of effective and efficient RCM:

(1) What are the functions and associated performance standards of the asset in its present operating context?
(2) In what ways does it fail to fulfil its functions?
(3) What causes each functional failure?
(4) What happens when each failure occurs?
(5) In what way does each failure matter?
(6) What can be done to predict or prevent each failure?
(7) What should be done if a suitable proactive task cannot be found?

Smith and Hawkins, (2004:95) further identify the following primary principles of RCM:

(1) RCM is function-oriented, it seeks to preserve systems or equipment;
(2) RCM is system focused, it is more concerned with maintaining system function than individual component function;
(3) RCM is reliability centred, it treats failure statistics in an actual manner;
(4) RCM acknowledges design limitations, its objective is to maintain the inherent reliability of the equipment design;
(5) RCM is driven by safety and economics. Safety must be ensured at any cost, thereafter cost effectiveness becomes the criterion;

(6) RCM defines failure as any unsatisfactory condition. Failure may be either a loss of function or a loss of acceptable quality;

(7) RCM uses a logic tree to screen maintenance tasks. This provides a consistent approach to the maintenance of all kinds of equipment;

(8) RCM tasks must be applicable. The tasks must address the failure mode and consider the failure mode characteristics and

(9) RCM tasks must be effective. The tasks must reduce the probability of failure and be cost effective.

Kelly (2006:159) identifies the following benefits of RCM:

- Traceability: this implies that all maintenance policy decisions are fully documented, maintenance experience reviewed and strategy updated.
- Cost saving: this implies that there is a general shift away from time-based or usage-based preventive maintenance towards condition-based maintenance with a consequent reduction of inventory and spare holding.
- Rationalisation: this is the identification of unnecessary preventive maintenance work; unachievable and uncontrollable maintenance workload is eliminated.
- Plant improvement: this implies that redesigning maintenance programmes and systems eliminates recurring failures or poor maintainability.
- Education: this is about the whole system of training and development and the overall level of skills and technical knowledge.

Peters (2006:269) identifies the following key elements of the RCM process:

- analysis and division on what must be done to ensure that any physical asset, system or process continues to do whatever its users want it to do;
- define what users expect from assets in terms of primary performance parameters such as output, throughput, speed, range and carrying capacity and
- identify ways in which the system can fail to live up to expression (failed state) and failure consequences.

According to Kirster and Hawkins (2006:98), RCM is a process used to determine the maintenance requirements of any physical asset in its operating context. Berger (2010:14) reports that RCM is an advanced technique for determining what preventive and predictive maintenance is required to keep an asset operating according to its original design and the operational requirements of its users. RCM is an approach to maintenance management that uses different types of maintenance for different parts of a process depending on their pattern of failure (Pycraft, 2010:595). The approach of RCM is sometimes summarised as: 'if failures cannot be stopped from happening, then failures better be stopped from mattering' (Pycraft, 2010:595). RCM is an approach or system that combines Total Quality Management with a strategic view of maintenance from process and equipment design to preventive maintenance (Heizer and Render, 2011:690). The authors, further identify the following characteristics of RCM:

- enables designing of machines that are reliable, easy to operate and easy to maintain;
- emphasises the total cost of ownership when purchasing machines so that service and maintenance are included in the cost;
- enables development of preventive maintenance plans that utilise the best practices for operators, maintenance departments and support services, and
- enables training for autonomous maintenance with maintenance personnel so that operators maintain their own machines.

The RCM process is unique in the manner in which it both recognises and manages hidden failures (Clarke & Young, 2011:35). According to Clarke and Young (2011:37) RCM uses a rigorous defensible and auditable process for developing the most appropriate strategy for managing the reliability of assets. It is a very robust tool with a proven track record for the management of operational risk. Clarke and Young (2011:36) identify the following RCM process outputs:

(1) listing of the functions of the system and the sub-system that it must perform;
(2) identification of the failed state, including 'too much', 'too little' and 'not at all';
(3) identification of the possible causes of failure, including failure that has occurred before;

(4) probable worst-case effect of the failure;

(5) allocation of the failure into the categories: hidden, safety or environment, operational and non-operational and

(6) determination of the most appropriate failure management.

3.3.3 Computerised maintenance management system (CMMS)

Most organisations understand the age-old syndrome of garbage in, garbage out but few manage to eliminate it. Irrespective of the fact that companies invest heavily in an integrated CMMS, it is felt by many that a very simple software programme could have provided the same value as this new, very expensive, system because neither of the two is being populated with accurate data and information (Hughes, 2001:133). Hughes (2001:134) identifies the following questions designed to help organisations to install an effective and efficient CMMS:

(1) Do the people who populate the system with data and information understand why they are doing it?

(2) Do they understand how each transaction or process contributes to the value of the company or their specific role in the company?

(3) Do they understand the main driving force behind any CMMS?

Hughes (2001:134) reports that many companies who implement a complex CMMS such as SAP R/3 PM, only utilise it to process work orders and do not utilise the information power it offers. In closing, Hughes (2001:136) identifies the following six steps for CMMS return on investment (ROI):

Step 1: the process is initiated by a database assessment to determine the status of the effectiveness of the system and by default determine the maintenance organisation;

Step 2: ROI benchmarks for each element are determined by benchmarking against world-class standards for obtainable returns from a CMMS implementation;

Step 3: a profit improvement plan (PIP) approach is used to focus on the specific return on investment goals;

Step 4: an end-state analysis is performed to determine the root cause that prevents the system from achieving its predetermined goal;

Step 5: the root causes identified are closed out as part of PIP, which can lead to a training needs analysis or business process re-implementation, and

Step 6: database assessments featuring actual business simulations are introduced to ensure the successful elimination of waste areas.

CMMS ROI model

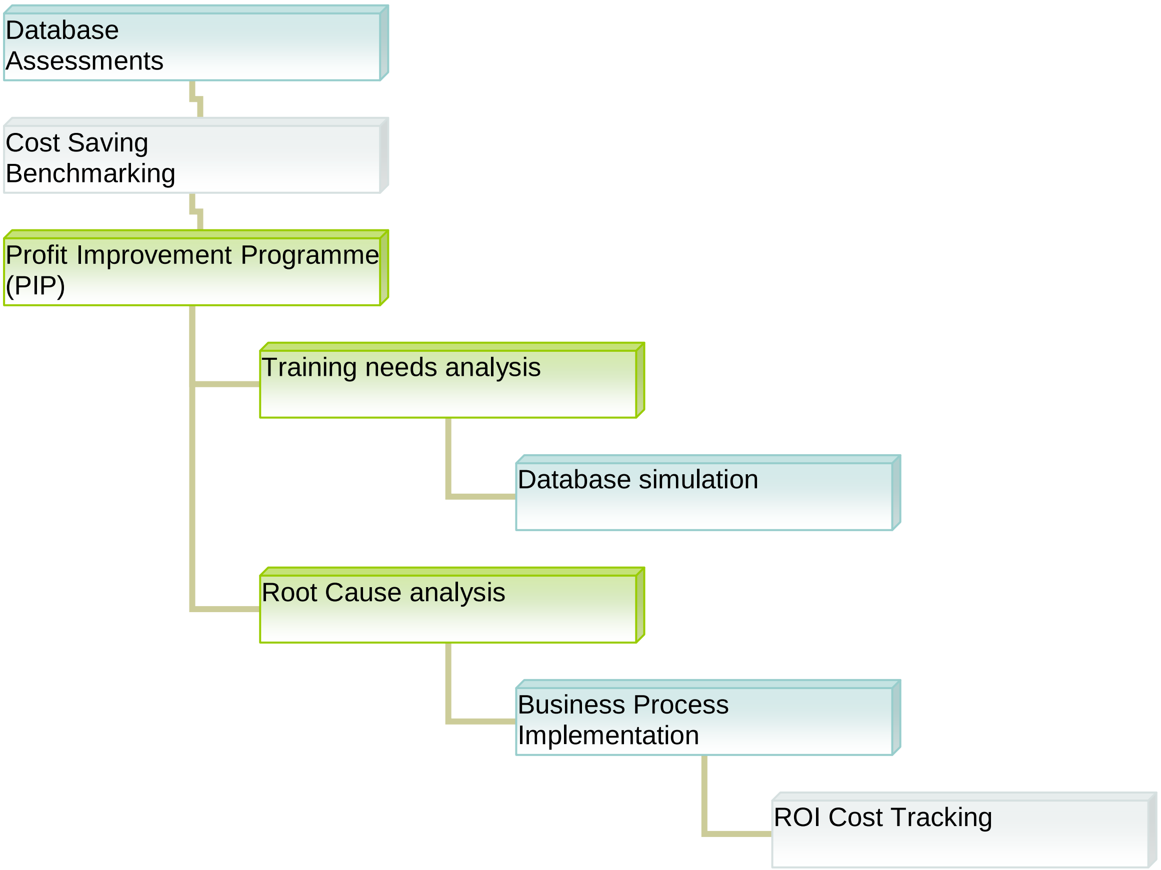

Figure 3.3 CMMS Return on Investment model
(Source: Hughes, 2001:137)

According to Cato and Mobley (2002:4), most organisations using CMMS have been able to achieve labour productivity rates of 70% to 80%, which is an improvement of at least 100%. Cato and Mobley (2002:4) claim that CMMS can improve labour productivity in several ways as listed below:

- accurate information about equipment or assets is readily available;
- planning time is reduced dramatically through the immediate availability of information required for planning;
- work order plans are accurate and complete;
- in most cases, a CMMS will provide resource scheduling assistance to ensure all resources (labour and materials) and

- an intangible benefit, one more difficult to measure in dollars, is improved employee morale because of better planning, scheduling and organisation.

Many companies have purchased a CMMS with the intention that the system will be the 'silver bullet' that solves all the maintenance problems, and indeed, it can, if it is properly implemented and its features effectively utilised (Smith & Hawkins, 2004:79). According to Smith and Hawkins*,* (2004:79) in order to obtain effective maintenance management information from CMMS software the following are the absolute requirements:

(1) all the facility's pertinent data must be entered;
(2) 100% data accuracy is a must and
(3) formats must be understandable to both user and the CMMS software.

Smith and Hawkins, (2004:82) maintain that all of the following elements must be covered in detail to achieve a singular, effective and integrated CMMS:

- work order control,
- planning and work measurement,
- materials support,
- preventive maintenance scheduling and levelling,
- scheduling and work assignment,
- equipment history and maintenance engineering support,
- cost accounting,
- budgetary control,
- equipment data (for example, equipment inventory listing, nameplate data, install date),
- maintenance procedural documentation (written step-by-step work instruction),
- equipment maintenance plans,
- preventive maintenance plans,
- corrective maintenance procedures,
- predictive maintenance procedures and
- output reporting formats (management reports).

A fully utilised CMMS to support the business of maintenance is an essential information technology tool (Peters, 2006:131). According to Peters (2006:131), the following are the key benefits of an improved CMMS:

- improved work control: better work management with improved control of work, management of backlog and determining priorities;
- improved planning and scheduling: better planning and scheduling of maintenance work;
- enhanced preventive and predictive maintenance: automatic scheduling of activities;
- improved parts and material availability: well organised stockrooms or stores with accurate inventory records, stock locator systems and accurate stock levels;
- improved reliability analysis, tracking of work orders, recording, retrieval and trending data and information;
- increased budget accountability: traceable materials, parts, spares, people and other costs;
- increased capability to measure performance and service and
- increased level of maintenance information.

3.3.4 Business centred maintenance (BCM)

According to Hughes (2001:6), BCM is a partnership of maintenance, production and engineering engaged in a joint venture to produce quality products at lowest costs. Hughes (2001:19) lists the following six pillars of BCM:

Pillar 1: early equipment management and maintenance prevention;

Pillar 2: training to improve skills of all people involved;

Pillar 3: improvement of equipment OEE by addressing the eight losses;

Pillar 4: involvement of operators in equipment management and daily effectiveness;

Pillar 5: improvement of maintenance organisation, efficiency and effectiveness;

Pillar 6: establishment of high impact teams to improve profit with cost saving details.

Hughes (2001:20) further highlights examples of BCM effectiveness from companies that are highly productive, illustrated in Table 3.1 below:

Table 3.1 Examples of BCM effectiveness from companies that are highly productive

Category	Examples of BCM Effectiveness
P (Productivity)	▪ Labour productivity increased ▪ Value added per person increased ▪ Production rate meets design rate
Q (Quality)	▪ Defects in process reduced ▪ Defects reduced ▪ Claims and/or complaints from customers and clients reduced
C (Cost)	▪ Reduction in manpower ▪ Reduction in maintenance costs ▪ Energy conserved
D (Delivery)	▪ Stock reduction – by days ▪ Inventory turnover increased ▪ Availability increased
S (Safety)	▪ Zero accidents ▪ Zero pollution
M (Morale)	▪ Increase in improvement ideas submitted ▪ Small group meetings increased

(Source: Hughes, 2001)

Hughes (2001:22) maintains that BCM addresses the following eight losses:

(1) Downtime losses

- shutdown losses: time lost when production stops for planned annual shutdown maintenance or periodic servicing;
- production adjustment losses: time lost when changes in supply and demand require adjustments to production plans;
- equipment failure loss: time when equipment suddenly loses its specified function and

- process failure loss: time lost in shutdown due to external factors such as changes in chemical or physical properties of materials being processed, operating errors or defective raw materials;

(2) Speed losses

- normal production loss: rate and time losses at the plant start-up, shutdown or change-over and
- abnormal production losses: rate losses occurring when the plant under-performs due to malfunction and abnormalities;

(3) Defects

- quality defect losses: losses due to production of reject products, physical loss of rejected products or financial loss due to product down grading;

(4) Reprocessing losses

- recycling losses due to passing material back through the process.

According to Kelly (2006:26), BCM is a framework or methodology for deciding maintenance objectives, formulating equipment life plans and plant maintenance scheduling, designing the maintenance organisation and setting up appropriate systems for documentation and control.

3.3.5 Risk based inspection (RBI)

RBI is a recommended practice that provides information on using risk analysis to develop an effective inspection plan, which is a system process that identifies facilities or equipment, and culminates in an inspection plan. It is based on the probability of failure and the consequence of failure (API, 2009:viii). According to API (2009:viii), the output of the inspection planning process should be an inspection plan for each equipment item analysed and this includes the following:

- inspection methods that should be used;
- extent of inspection (percentage of total area to be examined or specific location);
- inspection interval or next inspection date (timing);
- other mitigation activities and

- the residual level of risk after inspection and other mitigation actions have been implemented.

API (2009:2) identifies the following Risk Based Inspection maintenance benefits:

- an overall reduction in risk for the facilities and equipment assessed and
- an overall understanding of the current risk.

In addition, API (2009:2) lists the following limitations of Risk Based Inspection Maintenance:

- inaccurate or missing information;
- inadequate designs or faulty equipment installation;
- operating outside the acceptable or integrity operating window (IOW);
- not effectively executing the plans;
- lack of qualified personnel or teamwork and
- lack of sound engineering or operational judgement.

According to Vicente (2010:36), the Risk Based Inspection methodology is aimed at maximising the pressure vessel, vessel under pressure and pressurised systems' reliability and availability. Vicente (2010:36) mentions that the RBI methodology consists of the following five steps:

Step 1: Qualitative risk ranking: this is calculated by following the standard specification from API 580 and API 581 where the risk is defined as the product of the likelihood and the consequence (Risk = Likelihood X Consequence) as illustrated in Table 3.2 below:

Table 3.2. Risk Matrix

Consequence						
Probability	5	Medium High	Medium High	Medium High	High	High
	4	Medium	Medium	Medium High	Medium High	High
	3	Low	Low	Medium	Medium High	High
	2	Low	Low	Medium	Medium	Medium High
	1	Low	Low	Medium	Medium	Medium High
		A	B	C	D	E

(Source: Vicente, 2010)

Step 2: Assessment: this is done after determining the qualitative risk rating. It should cater for dimensions like mechanical behaviour, potential damage mechanism and maintenance strategy;

Step 3: Quantifying the inspection results: it identifies or determines the actual condition of the equipment, using approaches such as corrosion under insulation (CUI), non-destructive testing (NDT) and visual inspection;

Step 4: Fitness for service and remaining life assessment: it is needed to establish inspection intervals and a basis for reliability based inspection. It helps to determine the risk priorities relative to other plant that needs to be opened during the shutdown. Remaining life is calculated based on API 510 and pitting corrosion is evaluated in Chapter 6 of API 579;

Step 5: Root cause analysis (RCA): it identifies the basic root of the problem that affects the equipment performance audit's integrity.

Robbins (2011:47) lists the following characteristics of an effective risk-based inspection (RBI) maintenance. The characteristics are:

- it identifies global maintenance risks;
- it analyses and places risks in a considered ranking order;
- it has the means to determine the likelihood of occurrence and the impact of that occurrence where likelihood corresponds to issues around the device and impact to issue outcomes and
- it enables users to be holistic in considering the whole picture, to provide a means to target device maintenance so as to optimise resource utilisation.

3.4 DIMENSIONS OF MMS

This section describes the five dimensions of MMS, namely, the organisational structure and size which according to Wireman (2005:20) can be adopted to accommodate the maintenance management activities in a business. It also considers the role and importance of computer information and support, it explains what maintenance work measurement entails and how it could be used to enhance MMS. It further describes material support and control and lastly introduces the concept of maintenance planning, work scheduling and coordination as a maintenance activity.

3.4.1 Organisational structure and size

This section describes the three general organisational structures, which, according to Wireman (2005:20), can be adopted to accommodate the maintenance management activities in a business namely, the typical maintenance-centric organisational structure (MCOS), the typical production-centric organisational structure (PCOS), and the typical engineering-centric organisational structure (ECOS) as per Figure 3.4, Figure 3.5 and Figure 3.6 below.

The Typical Maintenance-Centric Org-Structure (MCOS)

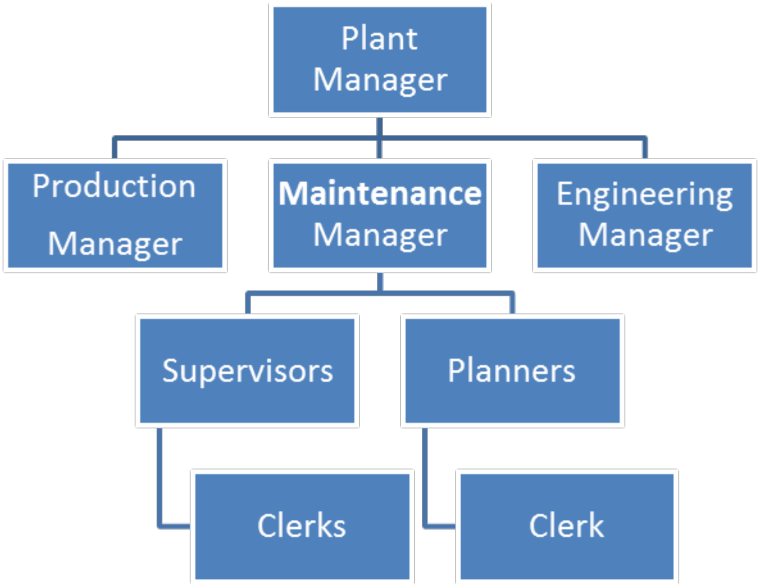

Figure 3.4 The typical maintenance-centric org-structure
(Source: Wireman, 2005:21)

In the maintenance-centric model (MCOS), maintenance reports to the plant or facilities manager at the same level as production and engineering. According to Wireman (2005:20), this model provides a balanced approach with the concerns of all three organisations weighed equally by the plant manager as per Figure 3.4 above.

The Typical Production-Centric Org-Structure (PCOS)

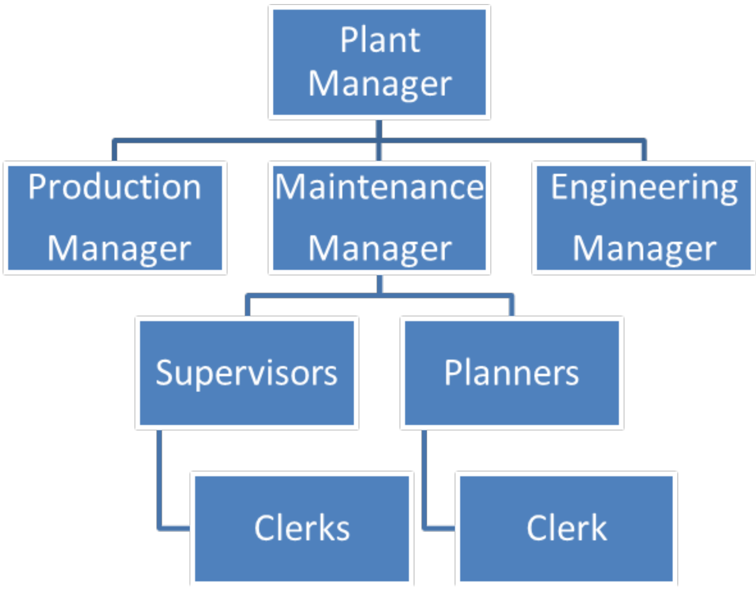

Figure 3.5 The typical production-centric org-structure
(Source: Wireman, 2005:21)

In the operations-centric organisational structure (PCOS), maintenance resources are deployed by the production or operations managers. To be successful, the model requires managers with sufficient technical skills to be able to deploy maintenance resources. According to Wireman (2005:21), when maintenance resources report to production or operations, maintenance generally deteriorates into the role of 'firefighting', or 'fix it when it breaks' as indicated in Figure 3.5 above.

The Typical Engineering-Centric Org-Structure (ECOS)

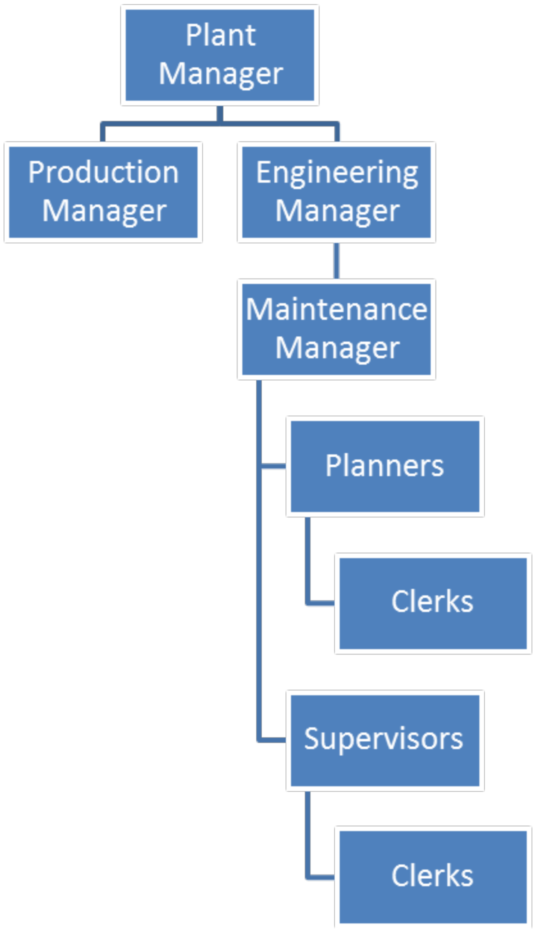

Figure 3.6 The typical engineering-centric org-structure
(Source: Wireman, 2005:22)

In the engineering-centric organisational structure (ECOS), maintenance reports to engineering. According to Wireman (2005:22) construction engineering, project engineering and maintenance all have the same supervision. Wireman (2005:22) further elaborates that if the project is behind, maintenance resources (people) are diverted from predictive or preventive maintenance to perform project work and equipment suffers from lack of maintenance (Figure 3.6 above).

The section further describes the seven style variations for organising maintenance operations as suggested by Kirster and Hawkins (2006:81-95) in an effort to assist in choosing appropriate maintenance organisational structure and size. The style variations are the trade organisation structure, area organisation structure, production department maintenance organisational structure, joint trade and area organisation structure, partial or total contract maintenance organisation structure, work type organisation structure and the combined style organisation structure. The following section will introduce the advantages and disadvantages of the seven style variations as suggested by Kirster and Hawkins (2006:81-95) as per Figures 3.7; 3.8; 3.9; 3.10; 3.11, 3.12 and 3.13 below.

(a) Organisation by trade

Advantages

- sufficient personnel are available to handle the work requirements of the plant;
- considerable flexibility is available in assigning personnel of different trades to the various jobs;
- the total number of personnel can be held reasonably stable, minimising hiring and layoffs;
- specialists (electrical and instrumental) are utilised more efficiently;
- special maintenance equipment is used effectively;
- one individual is responsible for all maintenance by skill or trade and
- accounting for all maintenance costs is centralised.

Disadvantages

- personnel are scattered around the plant and not closely supervised;
- time is lost in travelling to jobs;
- different personnel assigned to equipment: no one becomes proficient in repairs and
- interval between initial job request and completion for routine work can be longer and no one supervisor is responsible for total job completion, housekeeping or accountability.

The Trade Organisation

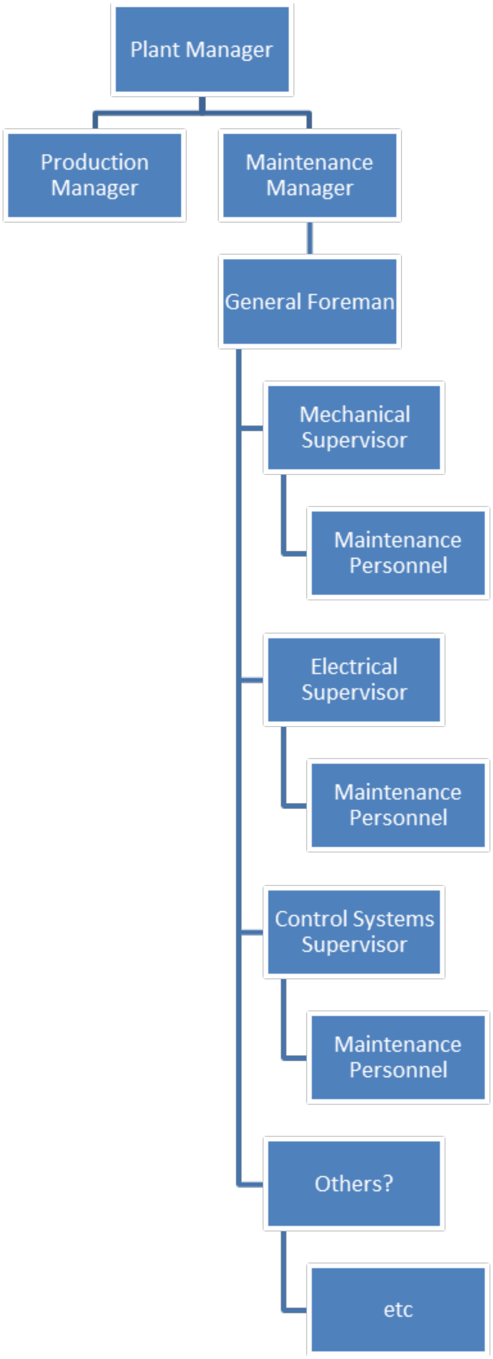

Figure 3.7 Trade organisation
(Source: Kirster & Hawkins 2006:83)

(b) Organisation by area

Advantages

- maintenance personnel are readily accessible;
- time spent travelling to a job is reduced;
- time lag is minimised between work request and work completion;
- maintenance supervisors and personnel become better acquainted with the equipment and its spare parts requirements;
- maintenance personnel are more closely supervised;
- production line or process change-over is faster;
- there is greater continuity from one shift to another and
- maintenance supervisors and personnel become more familiar with production schedules, problems and special jobs, for example.

Disadvantages

- there is a tendency to overstaff the area;
- major repairs are difficult to handle;
- there are more personnel problems and regulations pertaining to transfer, hiring and working overtime;
- duplication of equipment occurs in area maintenance shops;
- more clerical help is needed if the area groups are large and
- specialists are difficult to utilise effectively.

Area Maintenance Organisation

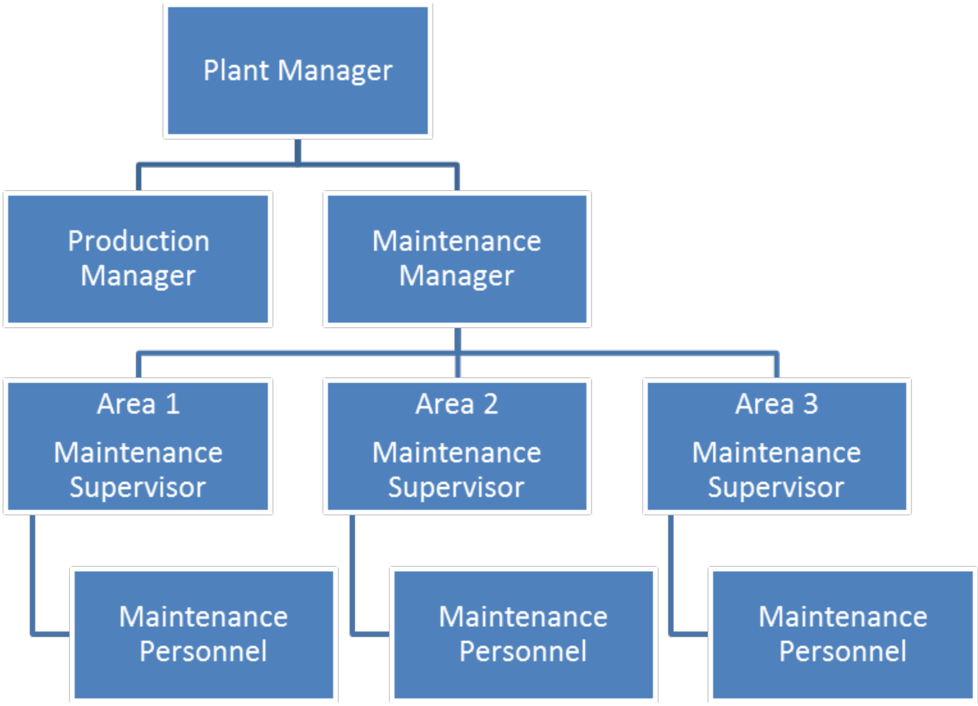

Figure 3.8 Area maintenance organisation
(Source: Kirster & Hawkins, 2006:85)

(c) Organising within production department

Advantages

- maintenance personnel are readily available to operations;
- time spent travelling to a job is reduced;
- time lag is minimised between work request and work completion;
- maintenance supervisors and personnel become better acquainted with the equipment and its spare parts requirements;
- maintenance personnel are closely supervised;
- production line or process change-over is done quickly;
- there is continuity from one shift to another and
- maintenance supervisors and personnel become more familiar with, for example, production schedules, problems, special jobs.

Disadvantages

- operations supervisors are not qualified to direct maintenance work;
- operations supervisors cannot give technical assistance to a mechanic;
- operations supervisor may neglect maintenance in order to meet schedules;
- the plant maintenance costs are harder to isolate;
- personnel problems are more pronounced than with area maintenance;
- there is a tendency to overstaff the area;
- major repairs are difficult to handle;
- there are more personnel problems and regulations pertaining to transfer, hiring and working overtime;
- special equipment is difficult to justify because usage may be limited;
- duplication of equipment occurs in the area maintenance shops;
- more clerical help is needed if the area groups are large and
- specialists are difficult to utilise effectively.

Production Department Maintenance

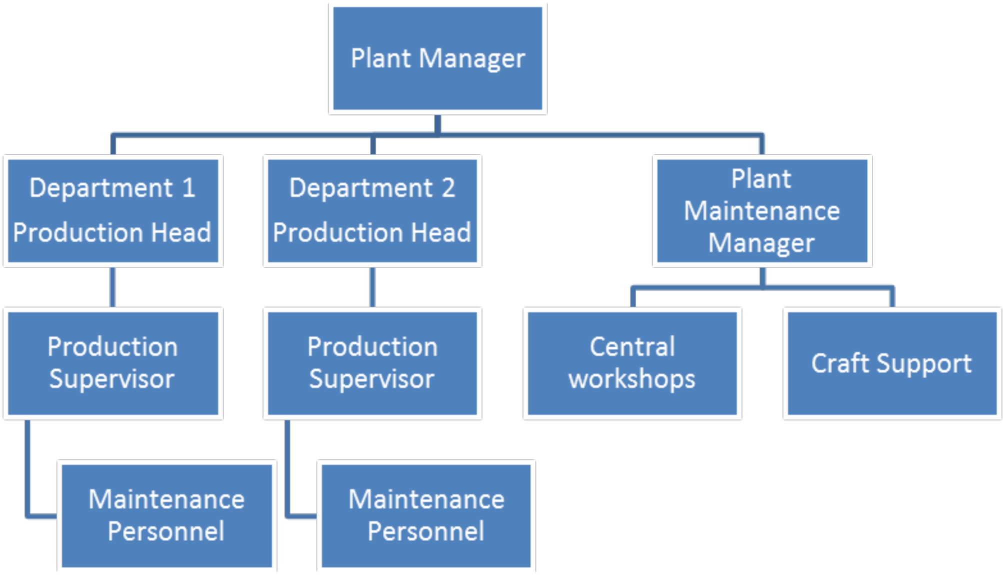

Figure 3.9 Production department maintenance
(Source: Kirster & Hawkins, 2006:85)

(d) Joint trade and area organisation structure.

Advantages

- existence of a group of central technicians capable of handling large projects and major repairs throughout the plant;
- there is good control of maintenance costs;
- area technicians are available to support production centres and
- area technicians are familiar with key equipment in the production centres and
- there is quick response.

Disadvantages

- central technicians are assigned to work throughout the plant resulting in high travel time and less job supervision;
- there is a tendency to prefer fixed crews;
- there is a tendency to overstaff an area;
- there is duplication of equipment and
- skills levels are not balanced properly.

Joint Trade and Area Organisation

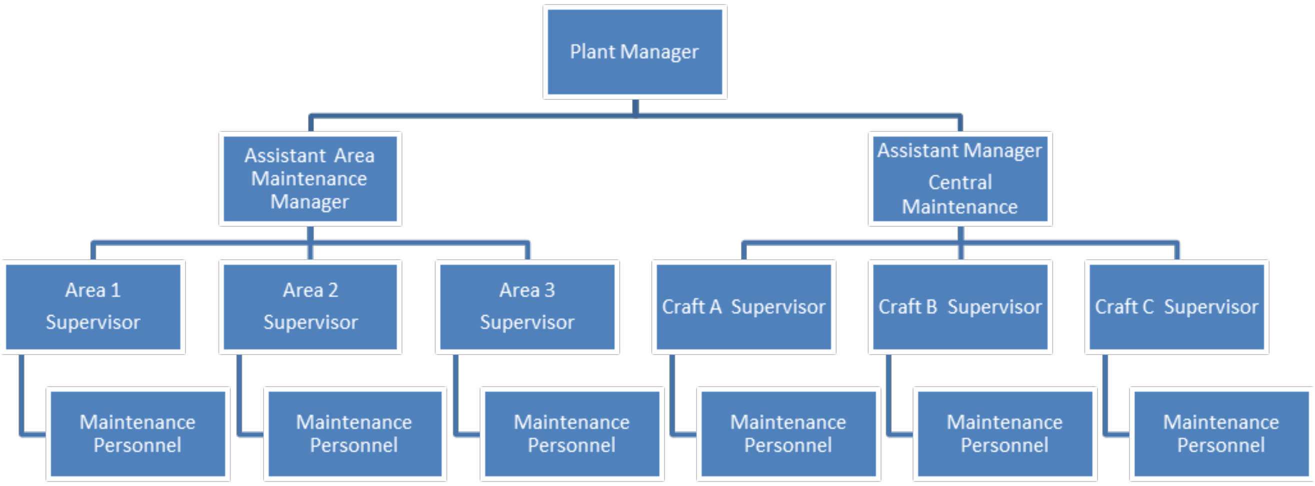

Figure 3.10 Joint trade and area organisation
(Source: Kirster & Hawkins, 2006:88)

(e) Partial or total contract maintenance

<u>Advantages</u>

- contractor theoretically has greater ability to flex staffing with workload;
- specific tasks can be targeted;
- specific trade skills do not need to be staffed;
- his often used where operating personnel are salaried and the technicians are not unionised and
- this is quite common in refineries.

<u>Disadvantages</u>

- it is difficult to communicate job details with workers;
- contractor shares no ownership in the equipment being maintained;
- it is also used in areas where labour rates are high and good job opportunities and
- makes retention of trades persons difficult and only possible at expensive hourly rates which destroy the balance of the wage structure.

Contracted (Outsourced) Maintenance Organisation

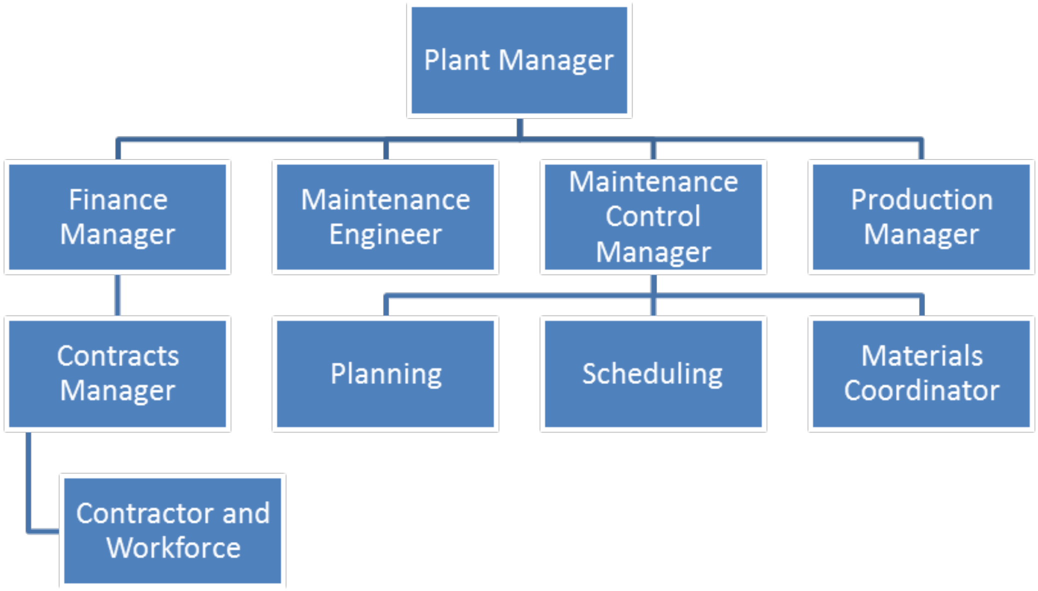

Figure 3.11 Contracted (outsourced) maintenance organisation
(Source: Kirster & Hawkins, 2006:89)

(f) Organisation by work type

<u>Advantages</u>

- there is clear accountability for each type of demand placed on the organisation;
- it is structured to cover the three principle types of maintenance work and
- skills and personality traits are matched to functions.

<u>Disadvantages</u>

- it is not easy to achieve in tough union environments;
- it requires a higher staffing level of multi-skilled personnel and
- personnel tend to get locked into specific functions and tend to lose focus on the 'big picture'.

Organisation by type

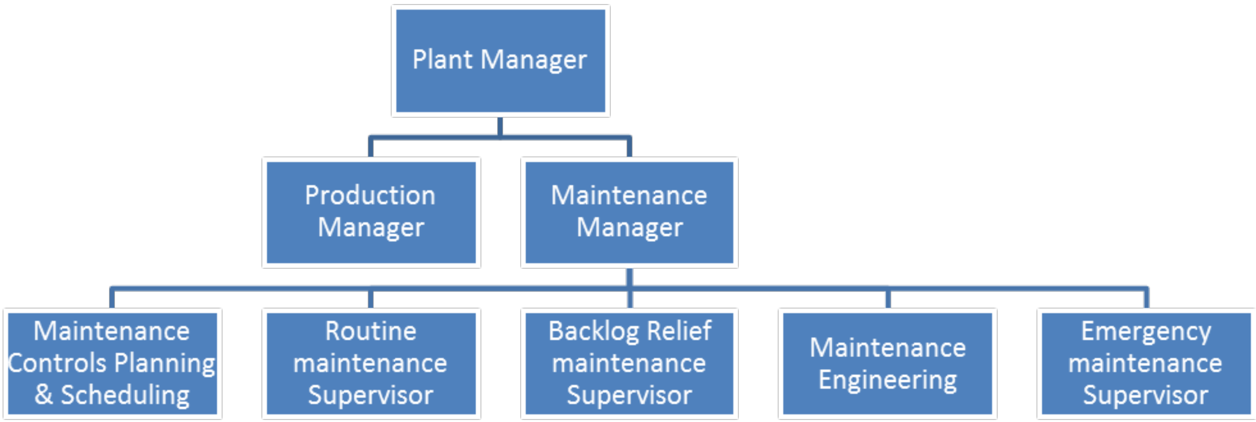

Figure 3.12 Organisation by work type
(Source: Kirster & Hawkins, 2006:91)

(g) Combination styled organisation

This organisation combines work type with area teams and comprises both maintenance and production personnel.

Advantages

- teams are trained to recognise and correct basic day-to-day problems;
- participation, self-motivation and team responsibility is strongly emphasised;
- there is strong motivation towards training and versatility;
- it generates higher motivation and individual satisfaction;
- there is improved joint understanding and dialogue;
- it retains the best elements of the combined craft-area structure and
- it retains the best elements of the combination.

Disadvantages

- it fosters emergency response only;

- maintenance troubleshooting requires extensive process knowledge and
- maintenance is neglected in favour of meeting the production schedule.

Combination Styled Organisation Structure

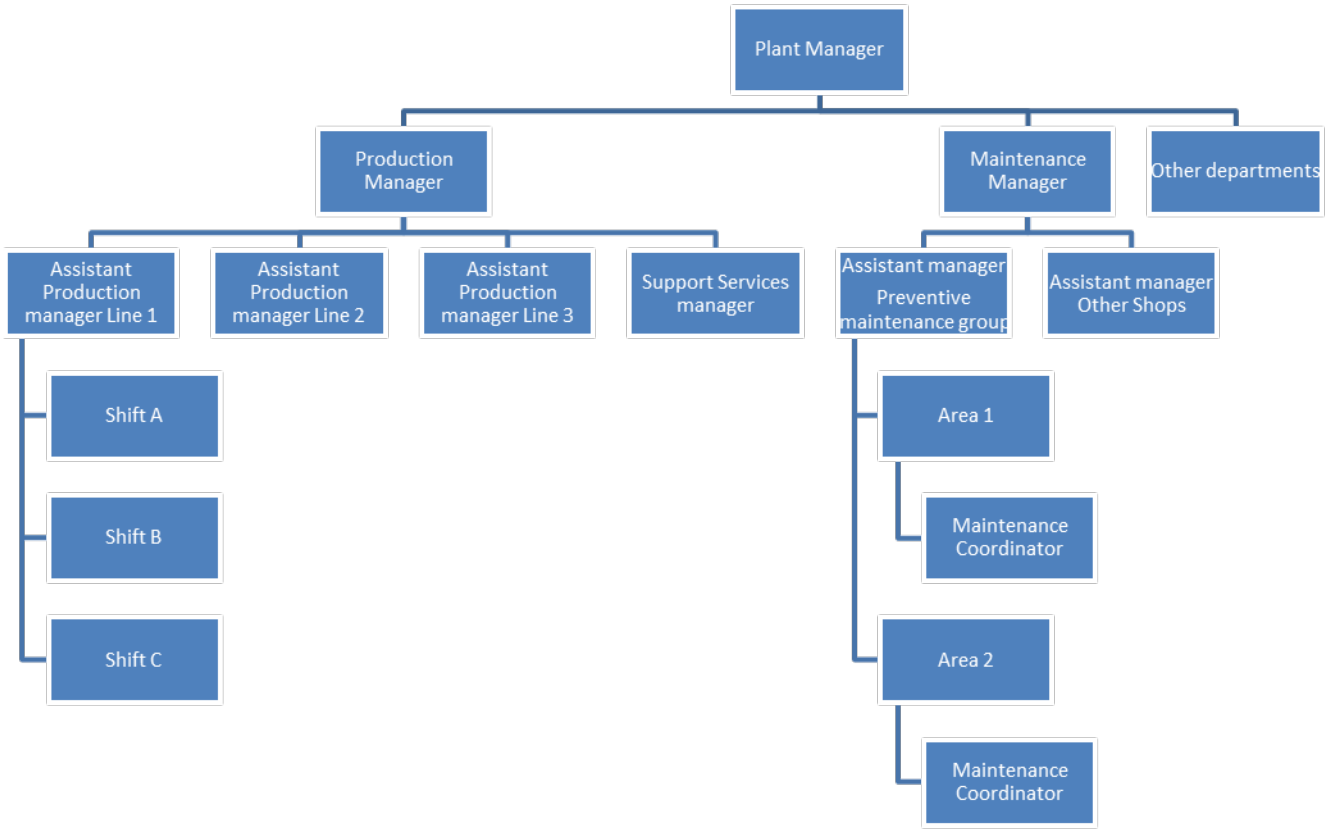

Figure 3.13 Combination styled organisation structure
(Source: Kirster & Hawkins, 2006:94)

3.4.2 Computer information and support

If Churchill was alive and working in our businesses today, he might be apt to say '…never have so many computer systems printed so much information of such little use' (Hughes, 2001:128). In the search for an effective information system, the first question that should be asked is …'what does it take to make an intelligent decision?' and the answer to this question is …'the knowledge of facts' (Hughes, 2001:128). Hughes further poses another question, which is …'what kind of knowledge?' and his response is …'unencumbered and closest to the source information'.

Hughes (2001:128) reports that the way to get information is usually by looking at the machine components or by having somebody tell you about it. He concludes by saying that the most effective information system is the first-hand knowledge of events. Most organisations understand the age-old syndrome of 'garbage-in, garbage-out', but few manage to eliminate it. Thus, irrespective of the fact that an organisation invests heavily in an integrated CMMS, it is felt by many that a very simple programme could have provided the same value as this expensive system because neither of the two is being populated with accurate data and information (Hughes, 2001: 133)

3.4.3 Maintenance work measurement

According to Mather (2004:11), measurements can be either formal or informal. He highlights that where there are no formal measurement systems in place, the performance is stated as being good, acceptable, poor, bad or any range of other qualitative measures. These measures, he contends, are often based on observed performance and are made against a perception of what the operations require. Mather (2004:11) further elaborates that formal measurement systems produce regular information regarding the key performance criteria of a plant, installation, item of equipment or other facet of work output.

Defining the levels of performance provides an understanding of how the equipment, people or other asset types are performing. Measurement systems highlight the level of improvement that is required to move from the current levels of performance to the desired levels of performance (Mather, 2004:11) as in Figure 3.14 below:

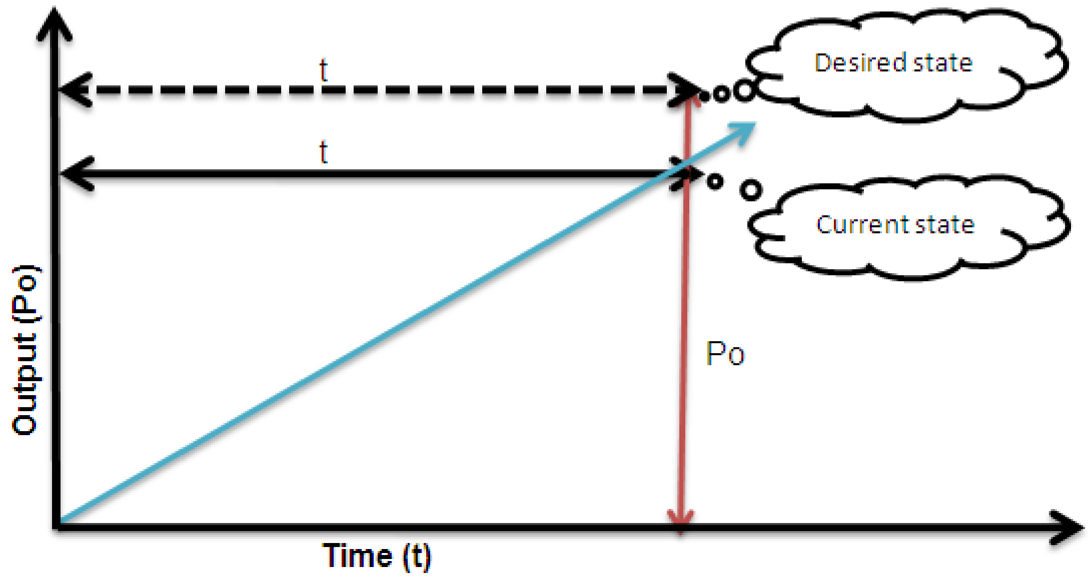

Figure 3.14 Defining performance model
(Source: Mather, 2004:12)

Mather (2004:12) claims that in order for a measurement system to be successful, there is a need to know and understand the following:

- What is the desired level of performance?
- How is the organisation going to determine the current levels of performance?
- What actions can be taken to improve performance from the current level to the desired level of performance?

To determine the prevailing state of performance, current practices employ the use of performance indicators and metrics (Mather, 2004:12). Mather (2004:16) identifies the following areas where there are myths in the measurements of maintenance performance:

- the use of metrics as a reactive measure rather than proactive measure;
- availability as effectiveness;
- misunderstandings of the levels where metrics are used;
- a general misunderstanding of benchmarking best practices and world-class classification and
- a brief that all performance measures are one dimensional metrics only.

Kirster and Hawkins (2006:162) list the following levels of maintenance work measurement methodology in Figure 3.15 below:

- supervisor or planner estimates;
- historical averages;
- published job estimating tables (construction trades);
- adjusted estimates or averages (based on work sampling during a base period);
- predetermined times;
- analytic estimating and
- time study and predetermined time formulas.

Levels of Work Measurements

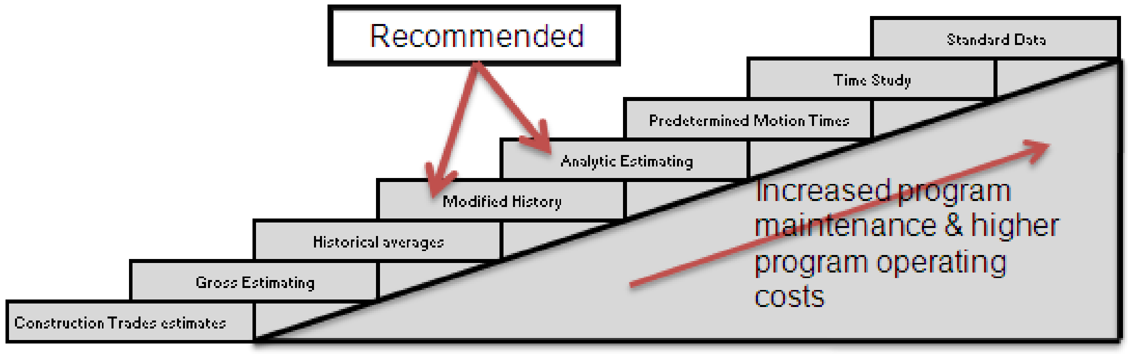

Figure 3.15 Levels of work measurements
(Source: Kirster & Hawkins, 2006:163)

3.4.4 Material support and control

Grutter (2010:220) identifies the following reasons why organisations must hold stock:

- to prevent raw materials stock-outs;
- independence of operations;
- more flexible production scheduling;
- anticipation of demands and
- economic order quantity savings.

Slack *et al.* (2011:201) identify the following disadvantages of holding inventory:

(1) Inventory ties up money in the form of working capital that is unavailable for other uses such as reducing borrowings or making investments in productive fixed assets.

(2) Inventory incurs storage costs (leasing space, maintaining appropriate conditions).

(3) Inventory may become obsolete as alternatives become available.

(4) Inventory can be damaged or can deteriorate.

(5) Inventory could be lost or be expensive to retrieve as it gets hidden amongst other inventory.

(6) Inventory might be hazardous to store (flammable solvents, explosives, chemicals and drugs) requiring special facilities and systems for safe handling.

(7) Inventory uses space that could be used to add value.

(8) Inventory involves administrative and insurance costs.

Most organisations will have an operations group, maintenance department, storeroom and logistics, procurement and purchasing and finance departments. The elephant is the storeroom and its materials and spare parts inventory (Slater *et al.,* 2013:22). According to Slater (2013:22), the maintenance department sees the inventory as one of the elements needed to efficiently repair the company assets. Stores, on the other hand, complain that maintenance has not stipulated the quantities and levels (lower and upper) of a particular part they really need. Procurement sees all the hard work to source the parts, locating obsolete parts, negotiating best prices and terms of payment and finance sees money tied up that they believe could be used better elsewhere.

3.4.5 Maintenance planning, work scheduling and co-ordination

An effective planning and scheduling function requires that reasonable estimates and planning times be established for as much maintenance work as possible (Peters, 2006:268). According to Peters (2006:268), the following are important factors for an effective and efficient maintenance planning and scheduling function:

(1) Planning times are essential; they provide a number of key benefits for the planning function:

- first, planning times provide a means to determine existing work load for scheduling by craft and backlog and
- second, planning times provide a target for each planned job.

(2) Getting started with the planning and scheduling function:

- setting up the structure by selecting qualified individuals to be planners;
- ensure ratio of one planner to 25-30 craft personnel and
- establish formal training for selected candidates.

(3) Focus on customer service

- all planning and scheduling personnel must understand their service role to customers.

(4) Measure effectiveness of the planning function

- develop and use performance measures to evaluate the return on investment and the effectiveness of the planning function.

3.5 MAINTENANCE SCORECARD (MS)

This section describes the history and evolution of the MS and explains the use of the MS tool through six different but integrated perspectives as proposed by Mather (2005:32). This section also describes some of the criticisms expressed about the MS tool, the six asset maintenance gaps identified by Mather (2005) and lastly it explains the application of the MS tool,

3.5.1 The history of MS

According to Peters (2002b:3) MS was originally developed as the Scoreboard for Excellence in 1981, and it has evolved from over twenty years of successful application in many types of public and private organisation. MS is designed to evaluate the total maintenance operations within the scope of coverage for a manufacturing organisation (Peters, 2002b:3). In evaluating the MS tool, the following potential drawbacks were considered. Geitner and Galster (2000) point out that if enterprises choose to ignore information technology, the design and implementation of the MS will fail. Mather (2005) states that inadequate linking of metrics to the corporate objectives of the company leads to the failure of the MS. In addition, he agrees and confirms that using one specific measure to understand the effectiveness or overall performance of the plant or equipment will lead to the failure of the MS.

In evaluating the MS the following advantages were evident. The MS is a tool designed to assess, evaluate and determine the level and/or the position of the organisation with the application of the best maintenance practices and standards. It has evolved during over twenty years of successful application to many different types of public and private organisation and is used worldwide by different organisations, public and private (Peters 2002c:2). The MS assesses or evaluates the strengths and weaknesses of organisations regarding the status of using the foremost maintenance practices and standards (Peters, 2002c:3). He further stipulates that the MS addresses three dimensions: asset health (reliability, availability, maintainability and operability), asset performance (utilisation, effectiveness, efficiency and volumes) and asset provision (sales, revenue, profit, ROI).

Mather (2005) states that the MS approach provides companies with a tool to implement, assess and evaluate the level of maintenance throughout the company. He further adds that the MS approach is a means of facilitating innovative thought within the organisation, particularly in terms of new and more efficient means of creating economic growth or management of risks.

Mather (2005) reports that the MS is a tool for attacking specific problems or issues at a corporate, departmental or project level. Evans (2002) states that when using MS, organisations will become more strategically focused over the next five to ten years and succeed in measuring maintenance performance. Hendricks (2008) additionally points out that the MS helps to measure results, not efforts and helps organisations to recognise the balance between maintenance costs, customers, processes and people. He further concludes that the MS enables and systemises feedback and collaboration, thus providing tools for analysis and enabling drill down to the real cause. According to Peters (2006:49), the MS is still a proper tool to measure the status/level of asset management, maintenance and MMS in the organisation and compare/benchmark it to world-class norms. According to the developers of the MS assessment tool, the MS is still recommended (Peters, 2002c).

Mather (2005) agrees that while it is best to apply or implement the MS from the organisational standpoint, it can also be applied at a departmental level, a project level, or an equipment level. The previous section offered criticism against the use of the MS as a tool or instrument to measure the level of maintenance of equipment in an organisation or company but also offered the potential advantages.

MS focuses on plant maintenance as the organisational global benchmark for maintenance best practices (Peters, 2006:43). The evolution of the MS is summarised in Table 3.3 below:

Table 3.3 Evolution of MS

Date of evolution	Scorecards Version	Benchmark Categories	Benchmark Criteria	Focus area
1981	Scoreboard for Excellence	10	100	Plant maintenance and tooling services
1993	Scoreboard for Maintenance Excellence	18	200	Plant maintenance
2003	Scoreboard for Maintenance Excellence	27	300	Plant maintenance
2003	Scoreboard for Facilities Management Excellence	27	300	Facilities maintenance
2003	Scoreboard for Healthcare Maintenance Excellence	27	300	Healthcare facilities maintenance
2004	Scoreboard for Fleet Maintenance Excellence	27	300	Fleet maintenance
2006	Scoreboard for Golf course Maintenance Excellence	30	300	Golf course maintenance/other green industry ops

(Source: Peters, 2006)

3.5.2 The MS tool

MS is a measurement technique that is used by many professionals. It is used for two main reasons: first, to measure performance against established goals and second, to help justify obtaining additional resources to assist the maintenance team in its mission of continuous improvement (Cowley, 2005:1). According to Mather (2005:9), MS is a methodology based on the measurement of performance and it is built around the use of management indicators, or metrics, to lead the development and implementation of strategy. Mather (2005:19) identifies the following objectives of MS:

(1) to facilitate the creation of corporate objectives or desired levels of performance;
(2) to facilitate the measurement of actual levels of performance;

(3) to provide a means of focusing the organisation on the improvement initiatives that are required to achieve corporate goals and objectives and

(4) to allow for easy and deliberate diagnosis of any deviations from the plans to achieve the desired levels of performance.

Mather (2005:25) claims that the ability of MS to focus the organisation and raise the visibility of the asset base manifests itself in the following three ways:

- an understanding of the capability and limitations of the asset base to achieve the goals of the organisation;
- an understanding of the data that will be required to effectively make decisions and manage this function and
- an understanding of the processes and initiatives required in order to meet corporate objectives and a thought out plan for achieving these objectives.

Mather (2005:27) lists the following benefits or advantages of implementing MS:

(1) inter-discipline and inter-departmental thinking and working;

(2) understanding the processes, acquisitions and initiatives required to achieve a desired end state;

(3) easy and deliberate diagnosis of any deviations from stated goals;

(4) a process for attacking specific problems or issues at a corporate, departmental or improvement project level;

(5) full use of corporate reporting tools where they exist, an understanding of the information portfolio required in asset management and some direction as to the technology to put this into place and

(6) the achievement of competitive advantage.

MS defines 'where the organisation is' in terms of applying today's best practices for plant maintenance. The MS provides a means to evaluate how the organisation is managing its six key maintenance resources, namely, people, technical skills, physical assets, information, parts and materials and the synergy of team effort (Peters, 2006:51).

According to Mather (2005:32), the MS has six perspectives/parts and he further defines the six perspectives or parts as follows:

(1) Productive perspective

This addresses how the asset management, maintenance and MMS can contribute to the capability to produce more. Hughes (2001:20) identifies the following basic requirements to enhance a productive perspective of MS:

- increased labour productivity;
- increased value added per person and
- production rate meets design rate.

(2) Learning perspective

This addresses how an organisation can continue to be innovative and use asset management, maintenance and MMS as an area of growth.

Learning perspective determines what training is meant to accomplish, and analyses the gap between the required skills and available skills to determine the amount and level of training necessary to close the gap (Smith & Hawkins 2004:226).

According to Smith and Hawkins (2004:234), maintenance personnel have often found it difficult to upgrade their technical skills because much that is available is redundant or does not take their current skills level into consideration. Smith and Hawkins (2004:234) further elaborate that maintenance skill assessment is a valuable tool to determine the strengths and weaknesses of a given group of employees in order to design a high-impact training programme.

(3) Quality perspective

This addresses how an organisation can ensure the repeatability of the performance of physical assets. Hughes (2001:20) identifies the following benefits of quality assurance and quality control:

- reduced defects;

- reduced client complaints or claims and
- increased improvement ideas.

Lenahan (2006:152) identifies the following basic quality requirements:

- quality means 'conformance' to requirements behaviour: this is about people that provide inputs to systems or processes, what they need to know and what is required of them in terms of their roles and responsibilities, standards and procedures;
- quality means 'fitness for purpose': this is about products produced, Products should meet the specifications and
- quality is an 'attitude of mind' that drives us to do our best: this is about the psychological factor of people performing tasks and activities and producing products.

(4) Environmental perspective

This addresses what an organisation can do to ensure that corporate exposure to environmental incidents is within tolerable limits. Hughes (2001:20) claims that highly productive organisations have zero pollution.

(5) Safety perspective

This addresses what an organisation can do to ensure that corporate exposure to safety incidents is within tolerable levels. Hughes (2001:20) insists that highly productive organisations have zero accidents. Mather (2005:37) lists the following elements for establishing and implementing a safety perspective dimension:

- reduction of incidents leading to lost time injuries, tangible benefits in higher employee productivity and lower incident related expenses;
- reduction of insurance premiums and
- increased employee morale, translating into reduced sickness leave and increased proactive action.

(6) Cost perspective

This addresses how an organisation can continue to reduce the unit costs of the asset management, maintenance and MMS efforts. Hughes (2001:20) identifies the following benefits of highly productive organisations with effective and efficient asset management, maintenance and MMS:

- reduction in manpower;
- reduction in maintenance costs;
- conserved energy;
- reduced stock (by days);
- increased inventory turnover and
- increased availability.

Cost minimisation in maintenance operation is a matter of not performing unnecessary maintenance (for example, increased labour costs, more off-line production time) and is also a matter of not missing required maintenance (reduced equipment reliability, equipment failures, production downtime) (Smith & Hawkins, 2004:27). However, Smith and Hawkins (2004:29) point out that to achieve this balance, sound reliability engineering is required to apply TPM, employing predictive maintenance techniques, condition monitoring and RCM (Figure 3.16 below).

Cost Minimisation

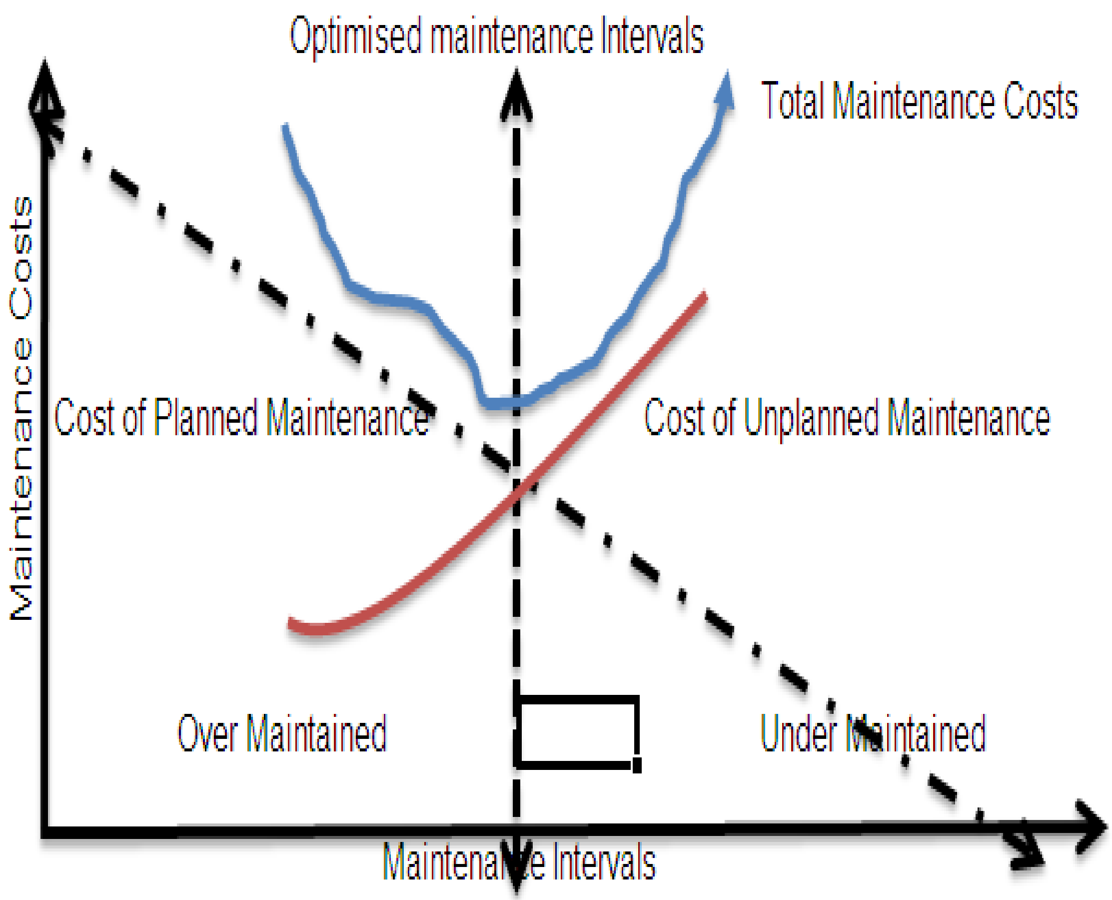

Figure 3.16 Cost Minimisation
(Source: Smith and Hawkins, 2004:29)

The Maintenance Scorecard Model

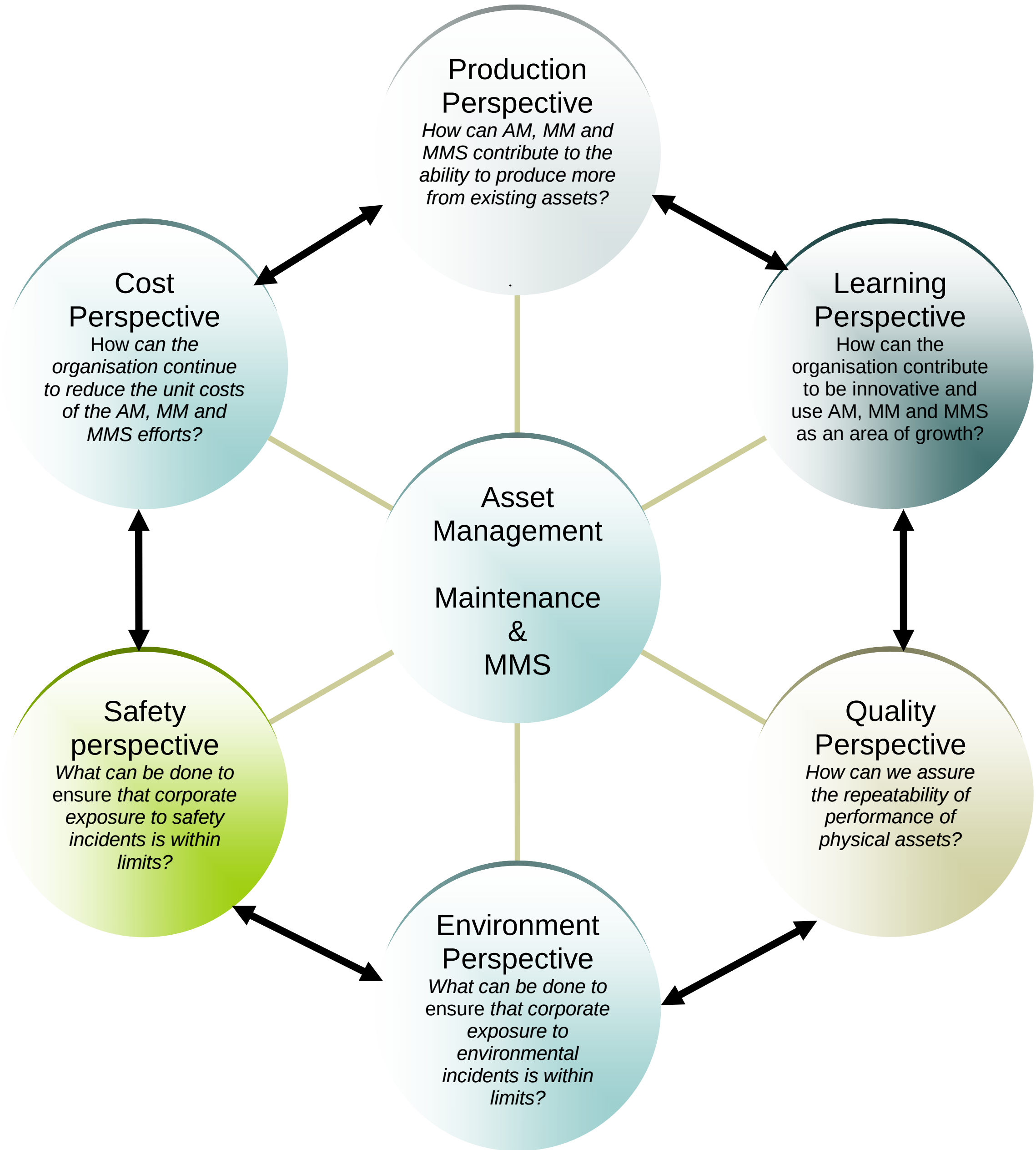

Figure 3.17 The Maintenance Scorecard Model as adopted from Mather (2005:32)

3.5.3 Criticism of the MS tool

Some of the drawbacks and criticisms of the MS tool were discussed in Chapter 1, section 5.5.1. Mather identifies the following myths (widely held, but false beliefs or exaggerated or idealised conception) and fundamentals of MS:

Myth 1: Metrics are treated as purely 'lagging' activities. According to Mather (2005:102), organisations view or utilise metrics as a continuous improvement tool that is useful for monitoring asset and human performance. In correcting this myth, Mather (2005:102) points out that metrics are a management tool for implementing corporate strategy and ensuring its execution. In addition, metrics highlights continuous improvement opportunities, which implies that metrics should be leading and lagging.

Myth 2: Availability is used as Overall Equipment Effectiveness (OEE). Mather (2005:103), states that organisations measure availability and call it effectiveness (OEE). In correcting this myth, Mather (2005:103) highlights that maintenance effectiveness is a concept that is not, and cannot be, represented by only one indicator. It is the product of availability, production rate and quality.
(OEE = Availability X Production rate X Quality).

Myth 3: Levels where metrics are used. According to Mather (2005:106), management uses indicators to monitor the performance of the organisation’s human and physical assets. He further points out that indicators are used by all levels of the maintenance organisation as a tool to assist in carrying out their daily tasks.

Myth 4: Performance measures are one-dimensional only. Mather (2005:107) reports that the organisation's performance measurement is only done through key performance indicators and standard metrics. He further claims that modern technology has enabled the use of sophisticated graphical analysis as well as one-dimensional indicators.

Myth 5: Proactivity is a measurable element. Mather (2005:109) points out that organisations believe and claim that proactivity leads to more efficient maintenance activities. As a result, measuring proactivity provides a snapshot view of how well the maintenance effect is performing. According to Mather (2005:109), proactivity is a source of efficient improvement: it is not easily measured and represents a form of thinking rather than measurable actions.

Myth 6: OEE is a measure of Overall Equipment Performance. Mather (2005:111) highlights that organisations view or regard Overall Equipment Effectiveness as a measure of the overall effectiveness of the equipment, plant or process. Mather (2005:111) contends that OEE is a useful measure if taken for what it is and if it is misused it can provide indications of performance that are inaccurate and at times dangerous.

However, despite the above myths, and the drawbacks and criticisms in Chapter 1, MS is still the most widely applied tool in maintenance excellence. This is evident because it is still identified as an appropriate measurement, assessment and benchmarking tool in recent textbooks and articles (for example, Cowley, 2005; Mather, 2004; Mather, 2005; Peters, 2002b; Peters, 2002c and Peters, 2006)

3.5.4 The MMS gaps

Mather (2005:32) identifies the following asset management, maintenance and MMSs gaps as per Figure 3.18 below and the gaps are as follows:

Gap 1: 'Asset Health Gap' - Gap between asset reliability, availability, maintainability, operability and PO (Production perspective);

Gap2: 'Asset Prioritisation Gap' - Gap between production and maintenance personnel in utilising correct priority rankings/ratings for critical tasks and activities (Safety perspective);

Gap 3: 'Asset Performance Gap' - Gap between asset efficiency, effectiveness, utilisation and PO (Environmental perspective);

Gap 4: 'Asset Provision Gap' - Gap between PO and profitability (Cost perspective);

Gap 5: 'Skills and working conditions Gap' - Gap between craft skills, competencies, experience, working conditions and productivity (Learning and growth perspective) and

Gap 6: 'Reliability and Quality Gap' - Gap between asset reliability and quality of products (Quality perspective).

The Asset Management, Maintenance and MMS Gap Model

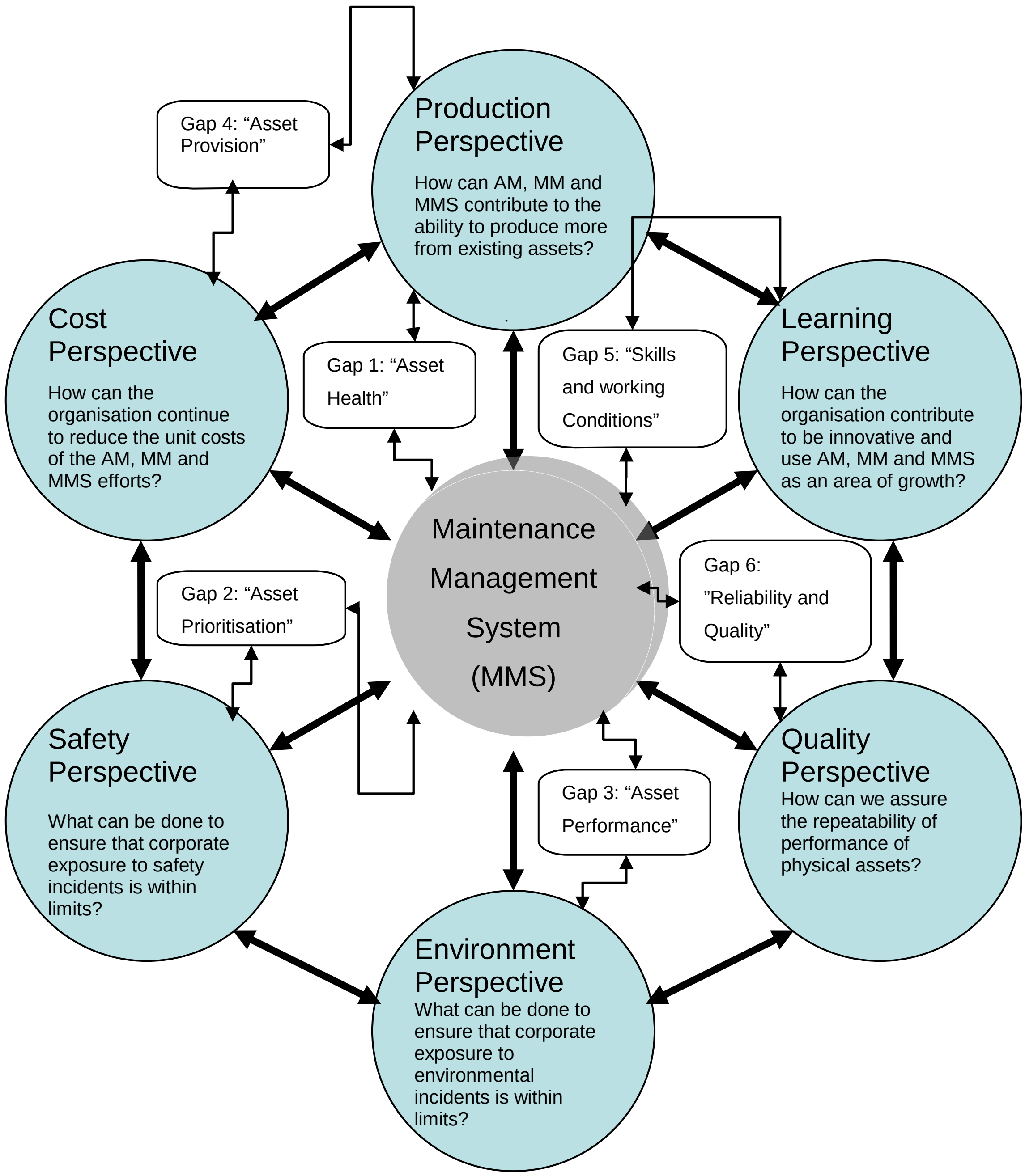

Figure 3.18 The Maintenance Scorecard Gaps as adopted from Mather (2005:32)

3.5.5 Application of the MS tool

According to Peters (2002c:2) the benchmarking process has evolved through twenty years of successful application in many different types of public and private organisations. There are currently five versions of scorecard for maintenance excellence:

- The Scorecard for Maintenance Excellence;
- The Scorecard for Facilities Management Excellence;
- The Scorecard for Fleet Management Excellence;
- The Healthcare Scorecard for Excellence and
- The Golf Course Scorecard for Excellence.

According to Cowley (2005:1), the MS can be used to justify the following:

- capital expenditure when production equipment maintenance costs are rising;
- additional overtime hours and pay for preventive and predictive maintenance work when manufacturing demands do not allow it on straight time;
- increased maintenance training when lack of knowledge is causing increased production downtime;
- additional contractor assistance when backlog man-hours are an upward trend;
- hiring a planner or scheduler to improve maintenance efficiency;
- increasing stock of maintenance supply parts when machinery downtime waiting on parts becomes a concern;
- component or system re-engineering based on equipment history of repeat failures and
- vibration and infrared programmes based on savings from equipment history of catastrophic failures.

According to Peters (2006:44), the following is a summary of various forms of benchmarking whereby MS can be applied:

- strategic benchmarking: improves an organisation’s overall performance by examining the long-term strategies and general approaches that have enabled high performers to succeed. this involves, for example, core competencies and developing new products and services;
- performance benchmarking or competitive benchmarking: considers the organisation’s performance in relation to its competitors;
- process benchmarking: focuses on improving specific critical processes and operations;
- functional benchmarking: focuses on different business sectors;
- internal benchmarking: involves seeking partners within the same organisation, for example, business units and
- external benchmarking: uses external companies to assess or audit maintenance performance.

3.6 CHAPTER SUMMARY

This chapter provided an overview of MMSs and was divided into three main sections.

Section 3.2 focused on the various types of MMS. Section 3.3 addressed the dimensions of MMS and section 3.4 addressed the history, criticism and application of MS and offered a detailed review of the MS tool. It was determined that the MS has a variety of applications in different industries.

Chapter 4 ('The Impact of Maintenance Management System on PO&P at the PetroSA GTL Refinery') focuses on production, production output, profit and profitability as the other constructs that form part of the main purpose of this study

Chapter 4: PRODUCTION, PROFIT AND PROFITABILITY

4.1 INTRODUCTION

The aim of this chapter is to provide an overview of the terms production, profit and profitability as they are used in this research. The previous chapter provided an overview of maintenance management systems (MMS) and the maintenance scorecard (MS) assessment tool. Section 4.2 of this chapter will introduce and discuss production. Factors such as the definitions of production, the transformation process model, the main production processes and production process performance measurement will be introduced and explained.

Section 4.3 of this chapter will serve as an introduction to profit and profitability. Factors such as the definitions of profit, the theories of profit, the objectives and the value of an organisation will also form part of the introduction. The chapter concludes with a discussion of the function of profit and the summary of Chapter 4.

The main sections of this chapter are outlined in Figure 4.1 below:

CHAPTER 4: PRODUCTION, PROFIT AND PROFITABILITY

4.1 INTRODUCTION

4.2 PRODUCTION

4.2.1 Definitions of production

4.2.2 The Transformation Process Model

4.2.3 The production process types

- 4.2.3.1 Continuous process
- 4.2.3.2 Batch process
- 4.2.3.3 Jobbing process
- 4.2.3.4 Project process
- 4.2.3.5 Mass process
- 4.2.3.6 Production process type per product

4.2.4 Production Process Performance Measurement

4.3 PROFIT AND PROFITABILITY

4.3.1 Definitions of profit

4.3.2 The theories of profit

4.3.2.1 Risk Bearing Theories of Profit

4.3.4.2 Frictional Theory of Profit

4.3.4.3 Monopoly Theory of Profit

4.3.4.4 Innovation Theory of Profit

4.3.4.5 Managerial Efficiency Theory of Profit

4.5 CHAPTER SUMMARY

Figure 4.1 Layout of Chapter 4

4.2 PRODUCTION

This section serves as an introduction to what production management entails including a review of definitions of production, the transformation process model, the production process types and the production process measurement focusing on the triple bottom line model; the demand theory; the Theory of Constraints (TOC) and the performance objective model.

According to Smith and Hawkins and Hawkins (2004:13), there are three laws of manufacturing or production that ensure global competitiveness and profitability and they are:

- properly maintained manufacturing or production equipment makes many good quality products;
- improperly maintained manufacturing or production equipment makes fewer products of questionable quality and
- in-operable equipment makes no products.

The following statements were extracted from some of the PetroSA GTL Refinery annual reports in an attempt to highlight the regular focus on production output and results. The PetroSA Annual Report (2008:21) reported the following feedback by the Chairman and President, Sipho Mkhize: “PetroSA GTL Refinery production volumes declined by 22% compared to 2007”. In support, the PetroSA Annual Report (2009:76) further highlighted the following feedback by the Chief Financial Officer (CFO) Nkosemntu Gladman Nika: “during the year 2009 the refinery production capacity was severely threatened by several factors that resulted in a 27% decline year-to-year”. Ika (PetroSA Annual Report, 2010:23) mentioned that PetroSA GTL Refinery production volumes in 2010 were low. The PetroSA Annual Report (2011:20) reported the following remarks by the CFO, Nkosemntu Gladman Nika: “PetroSA GTL Refinery production volumes were up by 25% compared to 2010”. In closing, the PetroSA Annual Report (2012:14) reported the following remarks by Nika: “PetroSA GTL Refinery production volumes for the year 2012 were low; as a result volumes were supplemented by traded (imported) products”.

4.2.1 Definitions of production

It is evident from literature that there are plenty of definitions of production, some of which were presented in Chapter 1. This section will briefly expand on additional definitions of production that have been proposed by several authors. Production refers to the transformation of inputs or resources into outputs of goods and services (Salvatore, 2001:238). Adding to this, Heizer and Render (2011:36) define production as "…the creation of goods and services". They further elaborate that the production process consists of inputs (labour, money and management), transformation process and outputs (goods and services). Render *et al.* (2011: 284) point out that the objective of the transformation process is to build a production process that meets customer requirements and product specifications within cost and other managerial constraints. They further claim that the transformation process selected will have a long-term effect on efficiency and flexibility of production as well as on the cost and quality of goods produced.

Jacobs and Chase (2011:196) highlight that production processes are used to make everything that we buy, ranging from the apartment building in which we live, to the ink with which we write. In addition, they point out that the production process is about sourcing parts (inputs), followed by making them (transformation) and sending the item to the customer (output). Blanchard and Johnson (2013:217) define aggregate production function as "a specification of the relation between aggregate output and the inputs in production".

For the purpose of this study production is defined as "transformation of inputs or resources into outputs of goods and services".

4.2.2 The transformation process

According to Heizer *et al.* (2011:45), the transformation model is an effective loop that evaluates performance against a strategy or standard and it also evaluates customer satisfaction and sends signals to managers controlling the input and the transformation process.

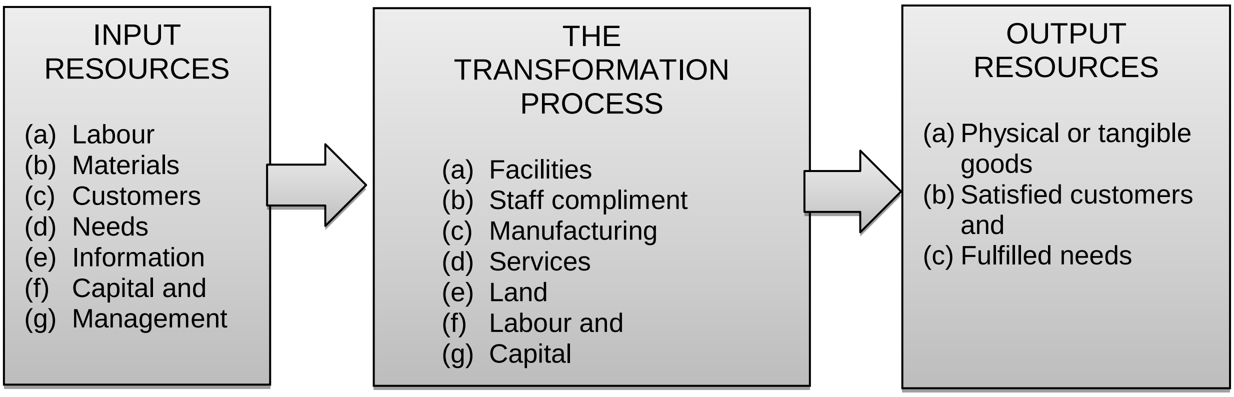

Figure 4.2 The Transformation Process Model
(Source: Slack *et al*., 2011:10)

4.2.2.1 The input to the process

Evans and Collier (2007:1) identify people, information and physical goods as key input resources to the production process. Supporting this statement, Slack *et al.* (2011:10) identify customers, materials and information as key input resources. Confirming the statement, Heizer *et al.* (2011:45) identify labour, capital and management as key input resources to the production process. In closing, Bozarth and Handfield (2013:22) add by identifying materials, tangible needs and information as input resources to the production process.

4.2.2.2 The transformation process

Evans and Collier (2007:1) identify land, labour, capital and information as key resources to enable the success of the transformation process. In support, Slack *et al.* (2011:11) list the facilities and staff as transforming resources that ensure success of the transformation process. In closing, Bozarth *et al.* (2013:22) identify manufacturing and services as key parts of the transformation process

4.2.2.3 The output to the process

Evans and Collier (2007:1) identify goods and services as key output resources in the production process. Supporting this statement, Slack *et al.* (2011:10) identify “pure” products and “pure” services as key output resources. Confirming the statement, Heizer *et al.* (2011:45) identify goods and services as key input resources to the production process. In closing, Bozarth *et al.* (2013:22) identifies tangible goods, fulfilled needs and satisfied customers as output resources to the production process.

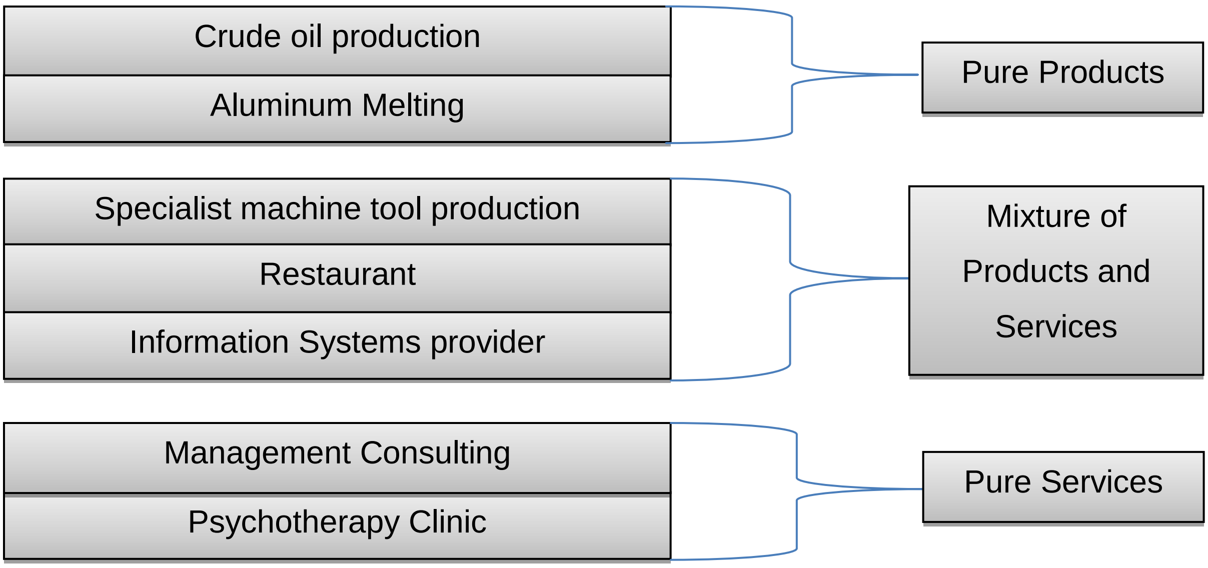

Figure 4.3 The output from most types of production processes
Slack *et al.,* 2011:12)

4.2.3 The production process types

According to Slack *et al. (*2001:126), each process type implies a different way of organising operations activities with different volume and variety characteristics. Slack *et al. (*2001:125) identify project, jobbing, batch, mass and continuous processes as key production/manufacturing process types. Adding to this, Grutter (2010:25) states that project management, job shop, batch production, assembly lines and continuous flow are key manufacturing/production process types. Supporting this, Ritzman and Malholtra (2010:118) list job shop, batch and continuous processes as key manufacturing/production process types. Slack *et al.* (2011:95) concur that project, jobbing, batch, mass and continuous processes are key manufacturing/production process types.

Heizer *et al.* (2011:72) agree that job shop, mass customisation, assembly lines and continuous processes are key manufacturing/production process types. In closing, Stevenson (2012:24) concurs that job shop, batch and continuous processes are key manufacturing/production process types.

For the purpose of this study, production process types are “project, jobbing, batch, mass and continuous processes”. These will be discussed in the next section.

4.2.3.1 Continuous production process type

According to Pycraft *et al.* (2001:128), continuous production process operates at higher volume and have lower variety. The process also operates for longer periods and their products are inseparable hence production is an endless flow. Adding to this, Evans and Collier (2007:262) indicate that continuous flow production process is very high fixed volume, high investment in equipment and facilities, automated movement of goods and 24/7 continuous operation

4.2.3.2 Batch production process type

According to Pycraft et al. (2001:127), batch process produces more than one product and it is a repetitive production process type. Adding to this, Stevenson (2012:241) mention that batch production process, is the production of items that are moved through different production steps in groups or batches.

4.2.3.3 Jobbing production process type

According to Pycraft *et al.* (2001:127), jobbing requires precision engineering and specialised skills; knowledge and experience. The degree of repetition is very low. Adding to this, Evans and Collier (2007:262) mention that job shop requires significant setup and/or change-over time, and is suitable for low to moderate volumes. In closing, Stevenson (2012:241) report that job shop is the production process type for highly customised products in quantities as small as a single product.

4.2.3.4 Project production process type

It deals with high customised products. The timescale of making the product is relatively long. It can be used for low or high volume production systems. Each job has a well-defined start and finish date and time; product has resources allocated or devoted exclusively to it and there is no repetition in producing products (Pycraft *et al.*, 2001:126). According to Evans and Collier (2007:262) the project process deals with large scale and complex resources brought to site and wide variation in specifications or tasks.

4.2.3.5 Mass production process type

This is the production process type that produces goods in high volumes and relatively narrow variety. It is a “mass” operation, repetitive and predictable (Pycraft *et al.*, 2001:127). Adding to this, Heizer *et al*. (2007:72) point out that mass customisation of high volume, rapid low cost production that caters for constantly changing unique customer needs

4.2.3.6 Production process type per product

Table 4.1 below indicates production process type per product

Table 4.1 Manufacturing/Production Process types per product

Type of production process	Examples of goods and services produced
Project	Space shuttle, dams, bridges, weddings, ship building, movie production, house or office building, pipelines, turbo-generators, oil wells drilling and installing computer systems
Job shop	Automobile engines, machine tools, shoes, commercial printing and machine shop
Continuous flow	Gasoline, paint, grain, chemicals, steel, paper, electricity utilities, institutionalized kitchen and bread
Mass	Refrigerators, toys, lawn mowers , furniture, automobiles, frozen pizza, beer bottling, television sets and CD production
Batch	Clothes, Component parts, machine tools and special gourmet food

(Source as adopted from Evans & Collier, 2007:262)

4.2.4 Production process performance measurement

It is no exaggeration with the view that production management as being able to either “make or break” any business (Slack *et al.,* 2011:46). This section comprises the triple bottom line, the Demand Theory, the Theory of Constraints and the performance objective model.

4.2.4.1 The triple bottom line model

According to Slack *et al.* (2011:47), triple bottom line is one common term that tries to capture the idea of a broader approach to assessing an organisation's performance. The objective of the triple bottom line is to measure economic profit and social and environmental impact. Slack *et al.* (2011:47) claims that a sustainable business is one that creates an acceptable profit for its owners but minimises damage to the environment and enhances the lives of the people with whom it has contact. According to Slack *et al.* (2011:47), the triple bottom line addresses the following key factors and/or pillars to ensure sustainability of an organisation (Figure 4.4):

(1) Planet: the environmental account measured by the environmental impact of the operation;
(2) People: the social account measured by the impact of the operation on the quality of people's lives and
(3) Profit: the economic account measured by profitability and return on assets.

Slack *et al.* (2011:48) identify the following characteristics of an organisation that invests in social development:

- acknowledging shared responsibilities for addressing global challenge and affirming that humanity does not stop;
- recognising that all individuals are equal in dignity and have the right to certain entitlements;
- embracing the importance of gender and the need for attention to the often different impacts of economic and social policies on women and men and
- affirming that a world connected by technology and trade must also be connected by shared values, norms of behaviour and systems of accountability.

In closing, Slack *et al.* (2011:50) identify the following five economic advantages for the organisations that implement and maintain the triple bottom line principles:

(1) reduced costs of producing products and/or services;
(2) satisfied customers through good quality of products and/or services;

(3) improved or increased revenue due to satisfied customers;

(4) reduced risk of production failures necessary to produce the required type and quality of products and/or services and

(5) provision of the basis of failure innovation by learning from its experience of operating its processes, thus building a solid base of skills, knowledge and capacity within the business.

Chase and Jacobs (2011:58) agree that the triple bottom line considers evaluating the firm against social, economic and environmental criteria. Chase *et al.* (2011:58) continue to elaborate that the social criteria pertains to fair and beneficial business practices, forward labour and common unity. In closing, Chase *et al.* (2011:58) report that economic criteria pertain to the firm's obligation to compensate shareholders and to promote growth and profitability and the environmental criteria refer to the firm's impact on the environment.

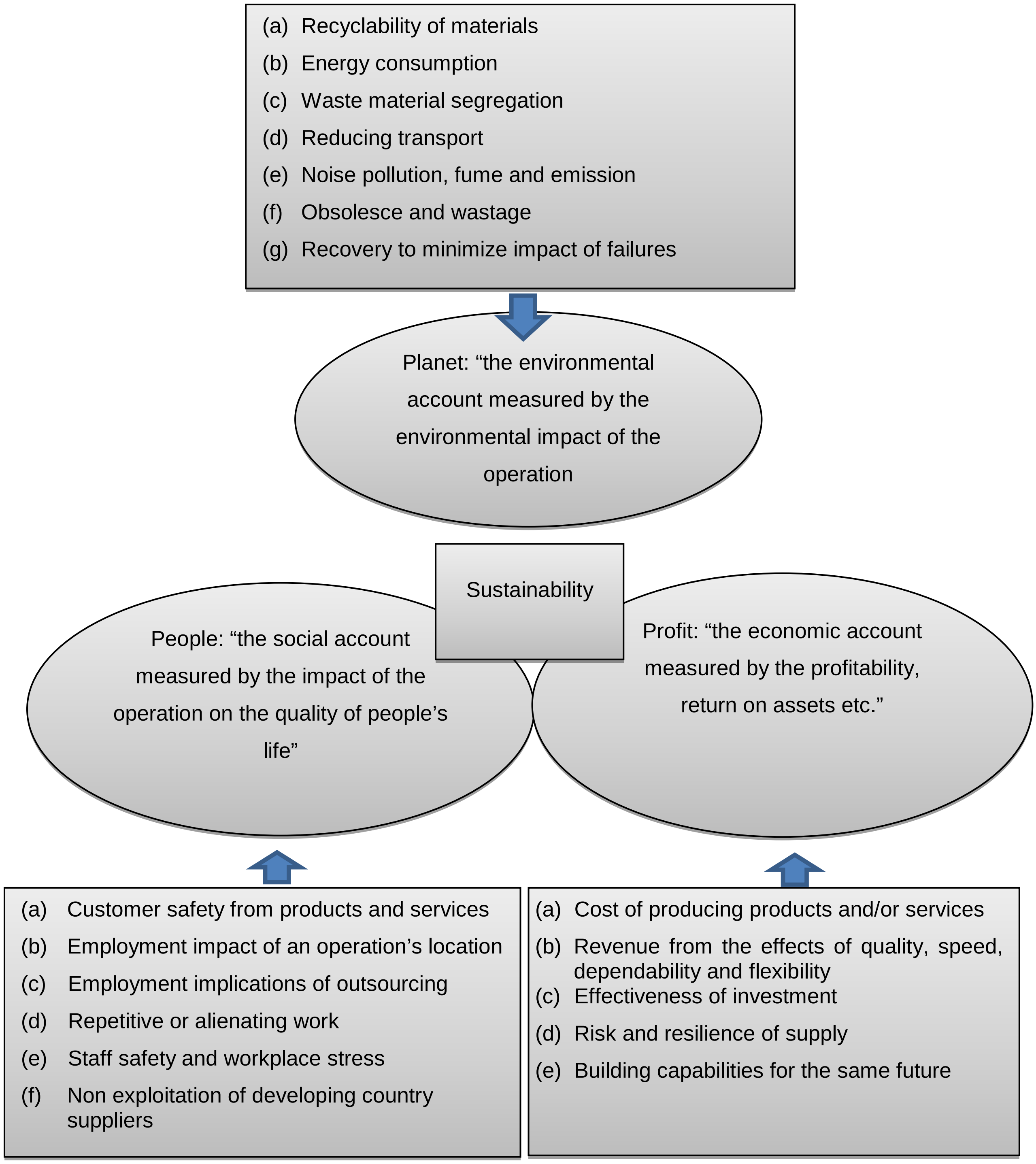

Figure 4.4 The Triple Bottom Line
(Slack *et al.*, 2011:47)

4.2.4.2 The Demand Theory

According to Salvatore (2001:90), an organisation could have the most efficient production techniques and the most effective management, but without demand for its product(s), it simply will not survive. Demand is essential for the creation, survival and profitability of an organisation. Salvatore (2001:106) highlights the following characteristics of demand:

(1) decline in price impact on total revenue increases if demand is elastic;
(2) total revenue remains unchanged if demand is unitarily elastic;
(3) total revenue decreases if demand is inelastic;
(4) marginal revenue is zero when total revenue decreases and
(5) marginal revenue is positive when total revenue increases.

According to Salvatore (2001:91), the Consumer Theory of Demand states that the quantity demanded of a commodity is a function of, or depends on:

- the price of the commodity (P);
- the consumer income (Earning);
- the price of related commodities and
- the taste of the consumer.

The quantity demanded of a commodity by an individual depends on the price and the individual will purchase more of a commodity if the price of a substitute commodity increases or if the price of a complementary commodity falls (Salvatore, 2001:91).

According to Wessels (2012:34), the Law of Demand states that "when the price increases, the quantity demanded decreases assuming other things do not change and these other things are the non-price determinants of demand and include such factors as income and taste". Wessels further lists the following benefits of the Law of Demand:

- the added buyer effect: this means that a lower price attracts new buyers;
- the income effect of a lower price: this implies that a lower price allows buyers to buy the same number of goods with less money and
- the substitute effect of a lower price: this is a relative price whereby a consumer gives up less of other goods to buy the good for which the price has decreased.

Miller (2012:49) agrees with the Law of Demand and states that "when the price of a good goes up, people buy less of it, other things being equal. When the price of a good goes down, people buy more of it, other things being equal". Hubbard and O'Brien (2013:127) support this and add that the Law of Demand is the rule that is holding everything else constant. When the price of a product falls, the quantity demanded of that product will increase and when the price of a product rises, the quantity demanded of that product decreases.

4.2.4.3 The Theory of Constraints (TOC)

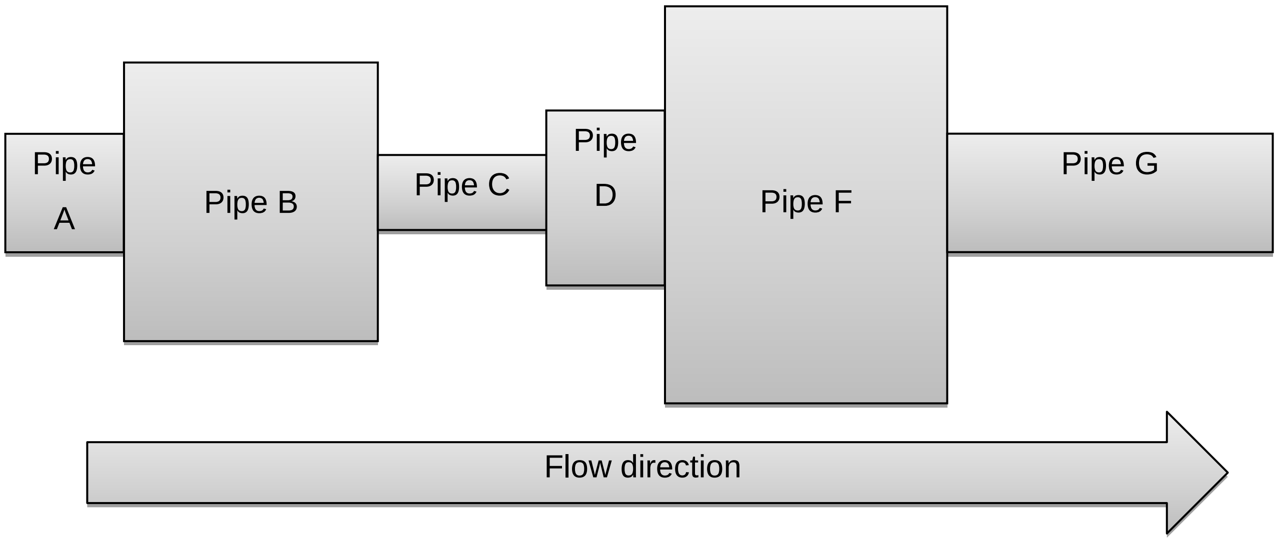

Figure 4.5 The Theory of Constraint Model
(Source: Bozarth *et al.,* 2013:175)

Goldratt (1990:7) lists and summarises the five-step approach of managing the constraints as follows:

(1) identify the system's constraints;
(2) decide how to exploit the system's constraints;

(3) subordinate everything to the above decision;

(4) evaluate the system's constraints and

(5) if in the previous step, a constraint has been broken, go back to step 1 but do not allow inertia to cause a system constraint.

Evans and Collier (2007:422) define TOC as "…a set of principles that focuses on increasing the total process throughput by maximising the utilisation of all bottleneck work activities and workstations". Evans and Collier (2007:423) list the following basic principles of TOC:

- only the bottleneck workstations are critical to achieving process and factory objectives and should be scheduled first;
- an hour lost at a bottleneck resource is an hour lost for the entire process or factory output;
- work in process buffer inventory should be placed in front of bottlenecks to maximise resource utilisation at the bottleneck;
- use large order sizes at bottleneck workstations to maximise setup and resource utilisation and
- bottleneck workstation should work at all times to maximise throughput and resource utilisation to generate cash from sales and achieve the company's goals.

Krajewski, Ritzman & Malholtra*.* (2010:285) identify and list the following key organisational measures relating to finance management as affected by TOC:

- a decrease in inventory leads to an increase in net profit, ROI and cash flows;
- an increase in throughput leads to an increase in net profit, ROI and cash flows;
- a decrease in operating expense leads to an increase in net profit, ROI and cash flows and
- an increase in utilisation at the bottleneck leads to an increase in net profit, ROI and cash flows.

Heizer *et al.* (2011:323) define TOC as "…a body of knowledge that deals with anything that limits an organisation's ability to achieve its goals". They further identify the following approach and tactics of managing the bottleneck:

- release work orders to the system at the pace set by the bottleneck's capacity;
- lost time at the bottleneck represents lost capacity for the whole system;
- increasing the capacity of a non-bottleneck station is a mirage and
- increasing the capacity for the bottleneck increases capacity for the whole system.

Bozarth *et al.* (2013:175) define TOC as "…an approach to visualising and managing capacity which recognises that nearly all products and services are created through a series of linked processes and in every case there is at least one process step that limits throughput for the entire chain".

4.2.4.4 The Performance Objective Model

Pycraft *et al.* (2001:48) list the following five performance objectives for any organisation that wants to succeed in the long term and mention that the organisation should:

- "do things right": the organisation must satisfy customers by providing error free products and services;
- "do things fast": it must minimise the time between a customer asking for goods or services and the customer receiving them;
- "do things on time": so as to keep delivery due dates;
- "change what it is doing": to enhance flexibility and adaptability and
- "do things cheaply": that is, produce goods and services at a cost that enables them to be priced appropriately for the market while still allowing for return on investment.

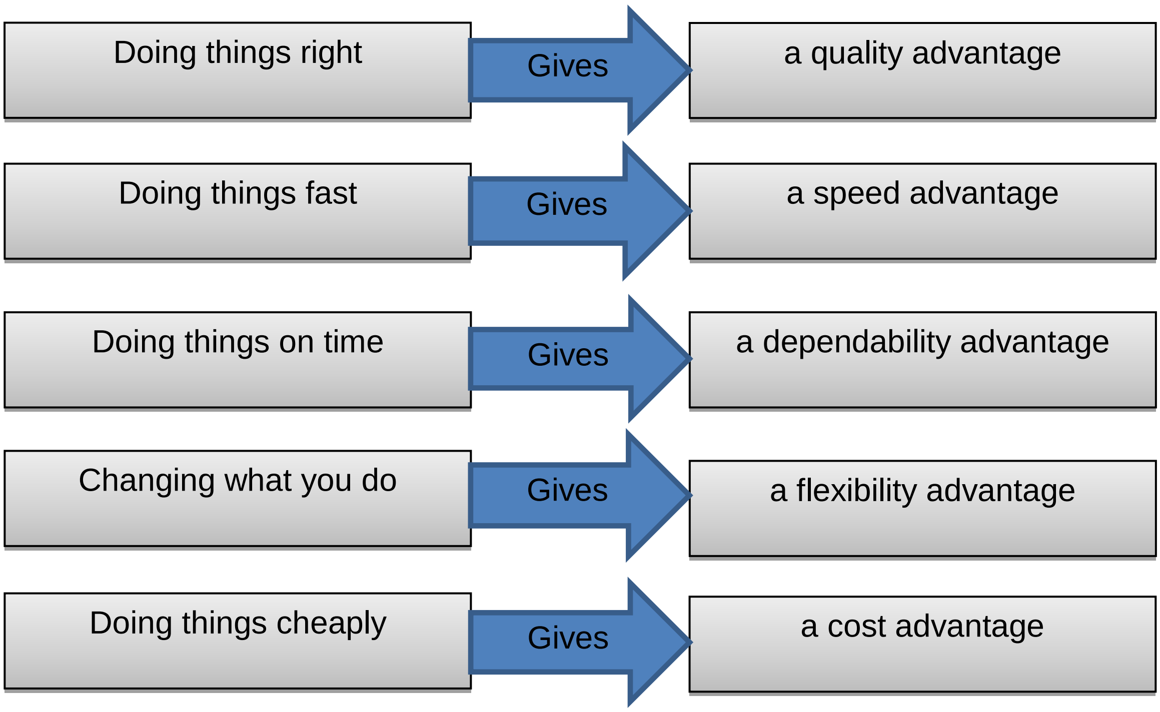

Figure 4.6 An operation contributes to business strategy by achieving five performance objectives
(Source: Pycraft *et al.,* 2001:49)

Evans and Collier (2007:74) identify finance, customer and market, safety, quality, time, productivity and innovation and learning as the scope of business and production performance measurement as illustrated in the table below:

Table 4.2 The Production Performance Measurement Model

Performance measurement category	Typical organizational level performance measures	Typical production level performance measures
Financial	▪ revenue & profit ▪ return on assets ▪ earnings per share	▪ labor & materials costs ▪ cost of quality ▪ budget variance
Customer and market	▪ customer satisfaction ▪ customer retention ▪ market share	▪ customer claims & complaints ▪ type of warranty failure/upset ▪ sales forecast accuracy
Safety	▪ number of accidents/injuries ▪ lost work days	▪ safety audit score ▪ workplace safety violation
Quality	▪ quality of goods & services ▪ environmental quality	▪ defect per unit ▪ call center courtesy ▪ toxic waste discharge rate
Time	▪ speed ▪ reliability	▪ flow processing/cycle time ▪ % of time meeting due dates
Flexibility	▪ design flexibility ▪ volume flexibility	▪ number of engineering changes ▪ assembly line change-over time
Innovation and learning	▪ new product development ▪ employee satisfaction ▪ employee turnover	▪ number of patent applications ▪ number of improvement suggestions ▪ % of workers trained
Productivity	▪ sales per square foot ▪ production costs	▪ shipment dollars per labor-hour ▪ units produced per labor-hour

(Source: Evans & Collier, 2007:74)

Bozarth *et al.* (2013:44) agree and add the following production dimensions:

- Quality: the characteristics of a product or service that bear on its ability to satisfy stated or implied needs;
- Delivery speed: how quickly the need can be fulfilled once it has been identified;
- Flexibility: how quickly can organisation respond to the unique needs of customers and

- Cost: includes labour, materials, engineering and quality costs.

Figure 4.7 below represents the performance objective model to be adopted by world class organisation to enhance competitiveness edge

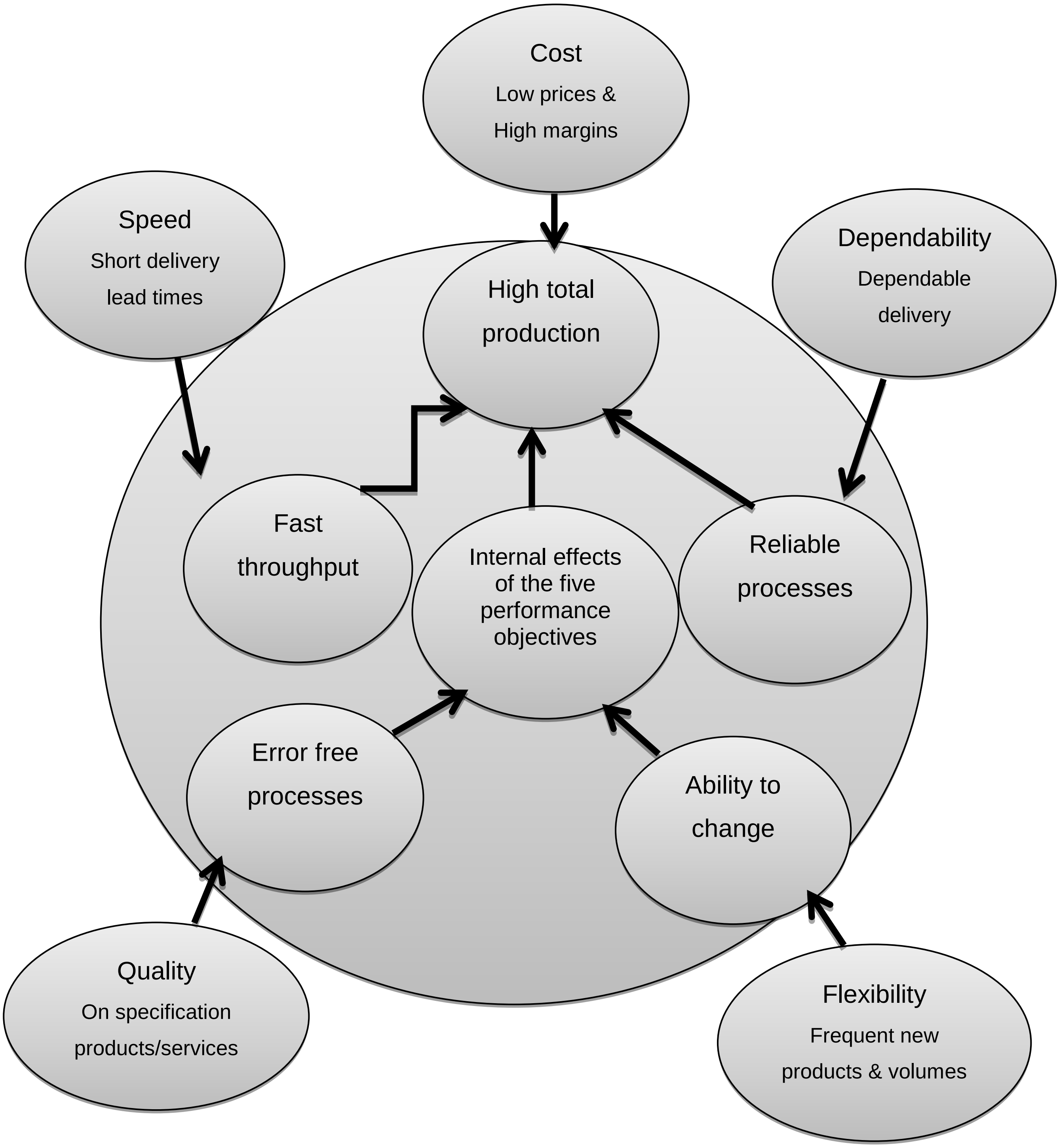

Figure 4.7 The Performance Objective Model
(Source: Slack *et al.,* 2011:61)

Figure 4.7 above indicates that in order to be competitive the organisations should pay more attention on the following:

(a) Quality of products: organisations must ensure that products are within set specifications. This is an external factor when reaction is from customers, internally, the organisation must put systems to support error free processes.
(b) Flexibility: organisations must be able to design and introduce new products. Organisations must be able to introduce and facilitate culture of change to embrace new ideas and thinking.
(c) Speed: this pertains timing of products to market and delivery to customer. The shorter the timing and the quicker products are delivered to customers, the happier are customers and this means more revenue and profits.
(d) Cost: organisations should control manufacturing costs in order that their prices be affordable. Organisations should introduce and manage high volume production in order to manage manufacturing costs.
(e) Dependability: clients and customers should be able to depend on organisations for quick or on time delivery. This depends on reliable and availability of manufacturing systems.

4.3 PROFIT AND PROFITABILITY

This section introduces and explain the concepts of profit and profitability, address and discuss the definitions of profit; the theories of profit with focus on risk bearing; frictional; monopoly; innovation and managerial theories of profit as used in this research. The section further explains the objectives and value of an organisation and the function of profit.

Salvatore (2001:14) claims that business profit refers to the revenue of the firm minus the explicit or accounting cost of the firm. Salvatore (2001:15) further elaborates that economic profit equals the revenue of the firm minus its explicit costs and implicit costs. In closing, Salvatore (2001:49) reports that profit is maximised when revenue equals the marginal costs or when marginal profit is equal to zero. Salvatore (2001:260) points out that to maximise profits organisations should employ each input until the marginal revenue product of the input equals the marginal resource cost of the input. Salvatore

(2001:282) elaborates that organisations will want to determine the amount of labour and capital needed to maximise profits rather than to maximise output or minimise costs.

According to Evans and Collier (2007:74), financial measures and measurement often take priority for profitability and in profitable organisations, cost and price are the obvious indicators for performance. Profitability is the primary goal of all business ventures; without profitability, the business will not survive in the long run (Hofstrand, 2009:1). The author further elaborates that measuring current and post profitability and projecting future profitability is very important. The following statements were extracted from some of the PetroSA GTL Refinery annual reports in an attempt to assess and analyse the financial and profitability performance of the organisation. The PetroSA Annual Report (2009:76) highlighted that the company (PetroSA) continued to operate profitably during 2009 despite the decline in production volumes due to high crude oil prices. The PetroSA Annual Report (2010:23) indicated that revenue for 2010 was 33% below the target and it further highlighted that sales volumes decreased by 79%: as a result, PetroSA reported a loss. In support, the PetroSA Annual Report (2011:20) reported that the company made a profit due to high crude oil prices. In closing, the PetroSA Annual Report (2012:14) reported that PetroSA achieved to make a profit due to high crude oil prices.

Sloman, Wride and Garratt (2012:165) identify two types of profits namely:

- normal profit: which is the opportunity cost of being in business. The profit that could have been earned in the next best alternative business, this is counted as a cost of production and
- supernormal profit: also known as pure profit, economic profit or simply profit. It is the excess of total profit above normal profit.

Sloman *et al.* (2012:222) point out that one criticism of traditional theory sometimes put forward as the difficulties in maximising profit is that firms do not use marginal costs and marginal revenues concepts. Sloman *et al.* contend that firms arrive at maximum profit by trial and error adjustment of price or by finding the output where total revenue and total costs are furthest apart. Heizer and Render (2014:227) claim that staying in business requires making investments and investments require making profits. They further elaborate that social and environmental sustainability do not exist without economic sustainability, of which it is appropriately allocating scarce resources to make a profit. Improvements in quality help firms to increase sales and reduce costs, both of which can increase profitability (Heizer & Render, 2014:244) as illustrated in Figure 4.8 below:

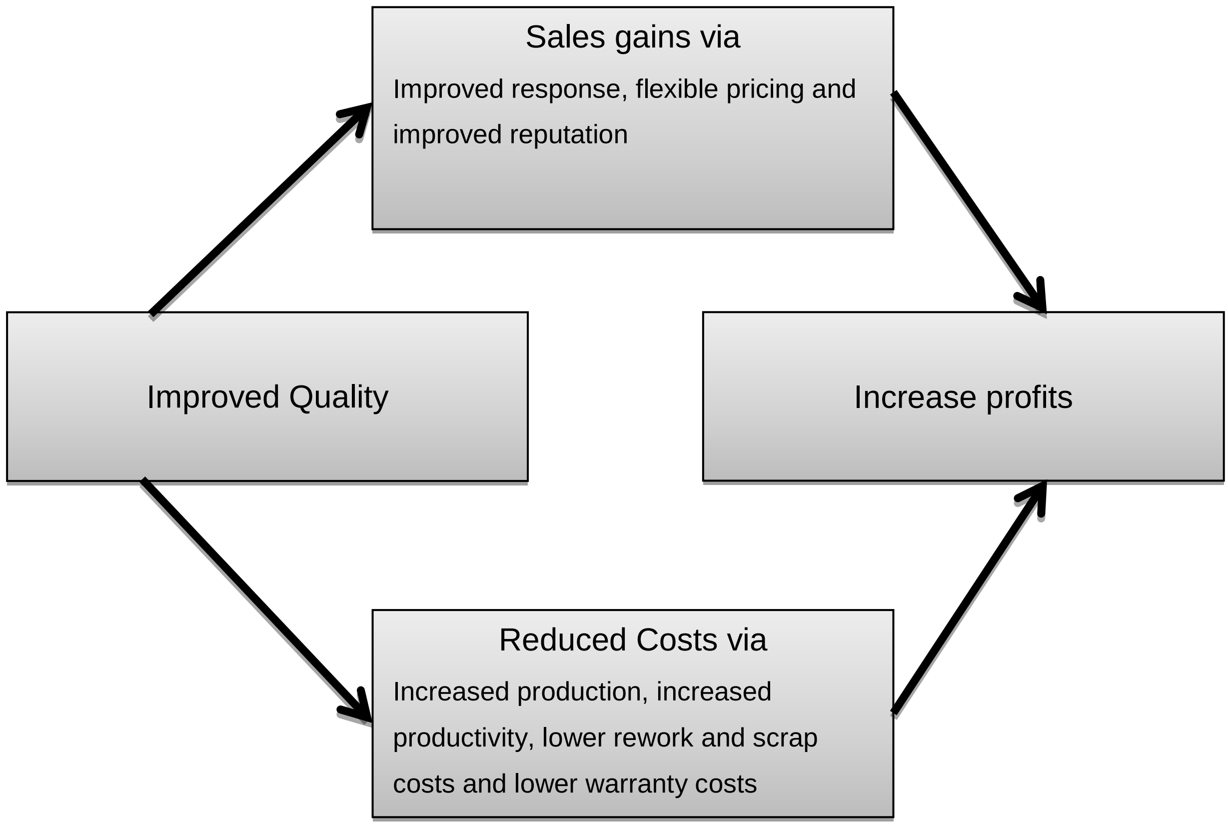

Figure 4.8 Ways in which quality improves profitability
(Heizer *et al.* 2014: 244)

In support, Hubbard *et al.* (2013:459) confirm that a firm maximises profit at the level of output at which marginal revenue equals to marginal costs. They further add that the difference between the price and average total costs equals profit per unit of output.

4.3.1 Definitions of profit

It is evident from literature that there are plenty of definitions of profit, some of which were presented in Chapter 1. This section will briefly expand on additional definitions of profit that have been proposed by various authors. Hofstrand (2009:2) defines profitability as either accounting profits or economic profits. De Villiers and Frank (2011:298) define profit as “the difference between total revenue and total costs, where total costs includes all costs”. In addition, they mention four conditions for perfect competition. The conditions are that:

- firms must sell a standardised product;
- firms must be prize-takers;
- there is free entry and exit, with perfectly mobile factors of production in the long run and
- firms and consumers have perfect information.

De Villiers *et al.* (2011:336), claim that the assumed objective of the firm is to maximise its profits. In addition, they state that the rule of PM in the short run is to produce the level of output for which price is equal to the short run marginal costs. In closing, De Villiers *et al.* (2011:337) argue that firms must actively seek out means of reducing the costs of doing business in order to maximise profits. Wessels (2012:539) defines economic profit as “…the excess of the total revenues over costs, including opportunity costs of the owner’s time and investment”. Miller (2012:11) defines profit maximising rate of production as “…the rate of production that maximises total profits or the difference between total revenues and total costs. Also it is the rate of production at which marginal revenue equals marginal costs”.

4.3.2 The theories of profit

Salvatore (2001:17) identifies the risk bearing, frictional, monopoly, innovation and managerial theories of profit. The following section will briefly highlight all these theories.

4.3.2.1 The Risk Bearing Theories of Profit

The Risk Bearing Theory of Profit implies that the expected returns on stocks have to be higher than on bonds because of the greater risk involved, for example, petrochemicals, oil and gas (Salvatore, 2001:17).

4.3.2.2 The Frictional Theory of Profit

The Frictional Theory of Profit stresses that profits arise from long run equilibrium; organisations earn normal return or zero profit on investment (Salvatore, 2001:17).

4.3.2.3 The Monopoly Theory of Profit

The Monopoly Theory of Profit is applicable to organisations with monopoly power: they can restrict output, charge higher prices under perfect competition and earn profit. Entry into this industry is restricted and organisations own and control the entire supply of raw materials required for production (Salvatore, 2001:18).

4.3.2.4 The Innovation Theory of Profit

The Innovation Theory of Profit states that profit is the reward for the introduction of a successful innovation (Salvatore, 2001:18).

4.3.2.5 The Managerial Efficiency Theory of Profit

The Managerial Theory of Profit rests on the observation that if the average organisation tends to earn only a normal return on its investment in the long run, organisations that are more efficient than the average would earn above normal returns and profits (Salvatore, 2001:18).

4.3.3 The objectives and value of an organisation

The function of an organisation is to purchase resources or inputs of labour services, capital and raw materials in order to transform them into goods and services for the purpose of sale. The goal or objective of an organisation is to maximise current or short-term profits, thus maximising the wealth or value of an organisation (Salvatore, 2001:11). To support and clarify this, Salvatore (2001:12) lists the following factors that hinder the success of an organisation:

- legal requirements (safety, health, environment, risk and security);

- environmental laws (such as emissions, spillages);
- capital (for example, funds, raw materials);
- land (space, location) and
- labour (skills, competencies, experience and knowledge).

4.3.4 The function of profit

According to Salvatore (2001:19), profit serves a crucial function in a free enterprise economy. High profits are a signal that consumers want more of the output of the industry. Salvatore (2001:18) further elaborates that high profits provide the incentives for organisations to expand output. The organisation with above average efficiency profits represents the reward for greater sufficiency. Lower profits or losses indicate that consumers want less of the commodity and/or that production methods are not efficient (Salvatore, 2001:19).

For the purpose of this study, profit is defined as"…the difference between total revenue and total costs, where total costs includes all costs".

4.4 CHAPTER SUMMARY

The chapter provided an overview of production, profit and profitability. The definitions of production and profit were introduced and discussed in sections 4.2.1 and 4.3.1. The transformational process model and the main production processes were also discussed in sections 4.2.2 and 4.2.3. The chapter further introduced and explained the triple bottom line concept, the Demand Theory and the Theory of Constraints concept. . Chapter 4 concluded with a discussion on the Performance Objective Model; the Theories of Profit and the Function of Profit.).

The next chapter will introduce and explain the research design. A more quantitative approach to measuring the triple constructs (MMS, PO and profitability) ratings would be the next step in studying the relationship between the MMS, PO and Profitability. As stated in Chapter 1 of this study, the primary objective was to investigate the MMS and the impact or influence on PO and Profitability at the PetroSA GTL Refinery.

Chapter 5: RESEARCH DESIGN

5.1 INTRODUCTION

The primary objective of this study was to investigate the impact of the maintenance management system (MMS) on production output (PO) and profitability at the PetroSA GTL Refinery, hence, the impact on the MMS as the independent variable and on PO and profitability as the dependent variables was studied. According to Cameron and Price (2009: XXI), the independent variable is a variable that is deliberately being altered in order to see the effect of this alteration upon another dependent variable. The dependent variable is a variable which changes as a result of a change to another variable. Hair, Celsi, Money, Samouel and Page (2011:450) state that the independent variable is a measurable characteristic that influences or explains a dependent variable, whereas the dependent variable is a phenomenon a business researcher wishes to understand, explain and predict. Welman & Kruger*.* (2001:16) agree that the independent variable is a factor that the researcher selects and manipulates in order to determine its effect on the observed problem being investigated and the dependent variable is that factor which the researcher observes and measure to determine how it was affected by the independent variable.

Zikmund, Babin, Carr and Griffin (2013:119) assert that the dependent variable is a process outcome or a variable that is predicted and/or explained by other variables, while the independent variable is a variable that is expected to influence the dependent variable in some way. The three constructs that were investigated were the MMS, PO and profitability. As such, the MS assessment tool was used on two different populations. This chapter deals with the research design for the study. According to Welman *et al.* (2001:46), the research design is the plan according to which research participants or subjects are sourced and information is collected from them. It is the description of how the participants are going to be managed with the view of reaching conclusions about the research problem or hypothesis or question. In support of this, Cameron and Price(2009:XXVIII) mention that the research design is the overall plan for the research, showing what will be done and/or observed in order to answer the overall research question or to achieve the research purpose. Hair *et al.* (2011:456) concur and state that the research design provides the basic directions or “recipe” for carrying out the research project. Adding to this, Zikmund *et al.* (2013:64) reveal that the research design is a master plan that specifies the methods and procedures for collecting and analysing the information needed.

The chapter will describe and address the research strategy that was formulated, the data collection methods, data analysis, research quality and the delimitations of the study. The chapter concludes with a discussion of research ethics. The main sections of this chapter are depicted in Figure 5.1 below.

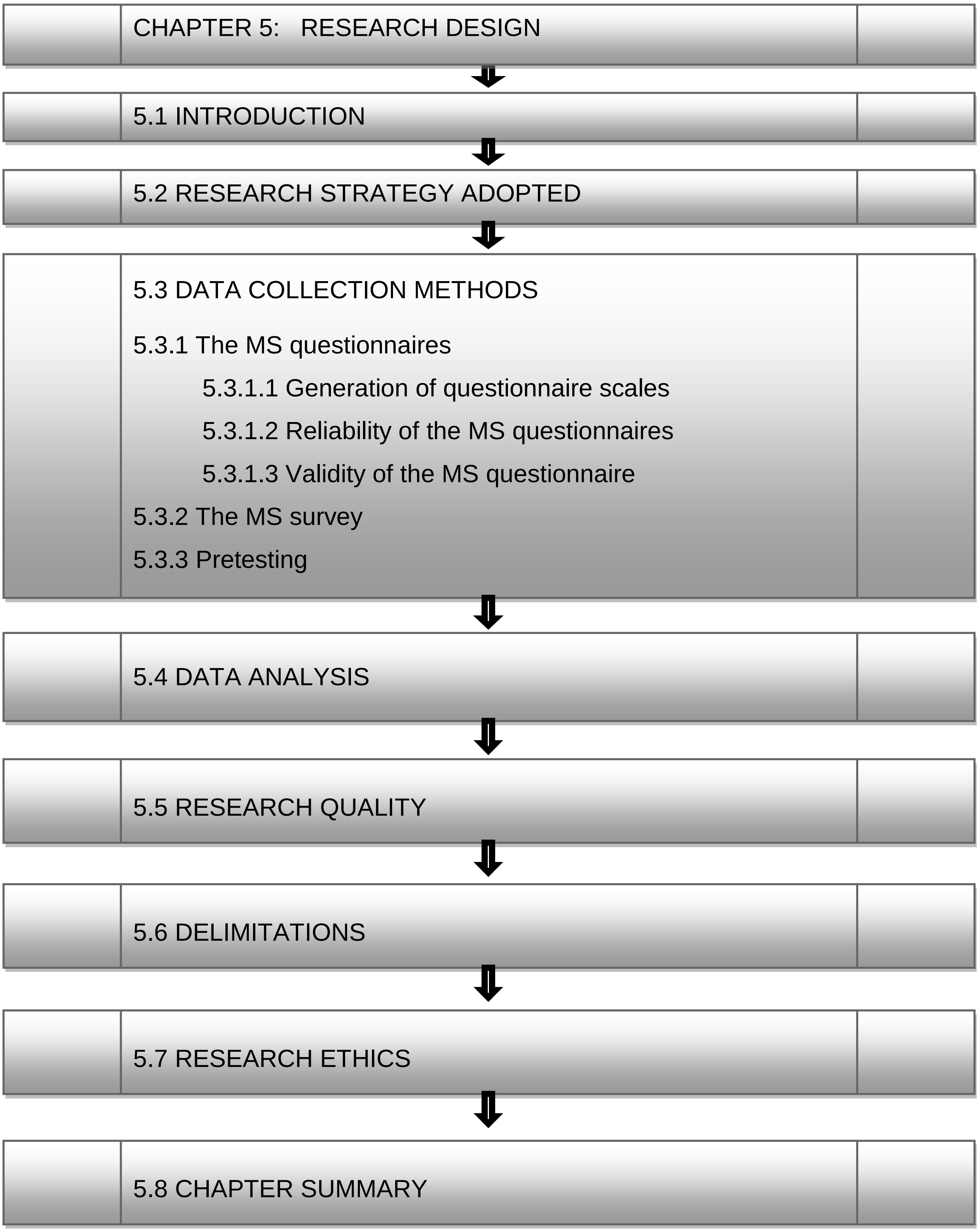

Figure 5.1 Layout of Chapter 5

5.2 RESEARCH STRATEGY ADOPTED

According to Saunders, Lewis and Thornhill (2012:128), the research philosophy that the researcher adopts can be perceived as their assumptions about the way they view the world. The authors (2012:127) define a research philosophy as "…the development of knowledge and the nature of that knowledge". This study was conducted using the positivism research philosophy. Cameron and Price *(*2009:73) state that positivism is linked to a belief that phenomena exist independently of the observer and can be detected through direct observation. The role of a researcher is to develop theoretical statements about the independent reality based on observation. The authors further elaborate that the hypotheses can be delivered from these theories and tested by means of further observation and analysis of results, methods and careful measurement, analysis, reliability, replicability and validity of measures are the "guarantor" of the knowledge generated.

Hair *et al.* (2011:454) state that positivism is a research philosophy that views reality as something that can be objectively ascertained and described through research. Welman *et al.* (2011:6) mention that the positivism approach underlies the natural scientific method in human behavioural research and that research must be limited to what can be observed and measured objectively. The research must exist independently of the feelings and opinions of individuals. In addition, the authors claim that the positivism approach is also known as the quantitative approach. Saunders *et al.* (2012:140) report that positivism philosophy is external objective and independent of social actions. According to Saunders *et al.* (2012:678), positivism research philosophy is the epistemological position that advocates working with an observable social reality and the emphasis is on highly structured methodology to facilitate replication. The product can be law-like generalisations similar to those produced by physical and natural scientists. In addition, the authors (2012:135) claim that the emphasis when using positivism research philosophy will be on quantifiable observations that lend themselves to statistical analysis, as in the current study.

Saunders *et al.* (2012:140) identify the following characteristics of positivism research philosophy:

- The researcher's view of the nature of reality or being is external objective and independent of social action.
- The researcher's view regarding what constitutes acceptable knowledge depends on observable phenomena that can provide credible data or facts; the focus is on causality and law-like generalisations and reducing phenomena to the simplest elements.
- The researcher's view of the role of values in research is undertaken in a value-free way; the researcher is independent of the data and maintains an objective stance.
- Data collection techniques most often used are highly structured, have large samples, perform measurements and follow a quantitative approach.

The researcher followed a deductive research approach in this study. According to Cameron and Price (2009:751), deductive research starts with theory and proceeds by testing hypotheses derived from the theory. Saunders *et al.* (2012:144) mention that in a deductive inference, when the premises are true, the conclusion must also be true. The authors (2012:669) further report that the deductive research approach involves testing of a theoretical proposition by the employment of a research strategy specifically designed for its testing. Saunders *et al.* (2012:145) list the following characteristics of the deductive research approach:

- first, there is a search to explain causal relationships between concepts and variables;
- second, the research would use a highly structured methodology;
- third, concepts need to be operationalised to enable facts to be measured quantitatively and
- last, the selection of sample data must be generalised

According to Welman *et al.* (2011:28) deductive research refers to the research in which a conceptual and theoretical structure is developed and then tested by empirical observation. Zikmund *et al.* (2013:43) agree that the deductive reasoning approach is a logical process of deriving a conclusion about a specific instance based on a known general premise or something known to be true.

The research methodology and approach followed in this study consisted of the quantitative approach to collect and analyse data and information. Page *et al.* (2003:321) report that the quantitative approach is the research approach that places value on information that can be numerically manipulated in a meaningful way: the traditional scientific approach to the research. In support of this, Zikmund *et al.* (2013:132) agree that quantitative research addresses research objectives through empirical assessments that involve numerical measurement and analysis. The authors (2013:162) elaborate further that quantitative research is generally associated with positivism, especially when used with predetermined and highly structured data collection techniques. The authors further add that the quantitative research approach is usually associated with a deductive approach when the focus is on using data to test theory, as in the current study. A quantitative research approach examines relationships between variables that are measured numerically and analysed using a range of statistical techniques. A quantitative research approach is principally associated with survey research strategies, as in this study.

The data collection methodology employed by the researcher consisted of quantitative surveys to study the MMS, PO and profitability practices at the PetroSA GTL Refinery. Page *et al.* (2003:324) mention that survey research is an instrument that enables a researcher to study a population sample in order to infer characteristics of a population (generalised findings). In support of this, Saunders *et al.* (2012:682) state that survey research is a strategy that involves the structured collection of data from a sizeable population. Zikmund *et al.* (2013:657) contend that survey research is the technique in which a sample is interviewed in some form or the behaviour of respondents is observed and described in some way.

A cross sectional study was followed in this study. According to Hair *et al.* (2011:446), a cross sectional analysis provides a snapshot of business elements at a given time. Adding to this, the authors (2011:121) state that cross sectional analysis is used when a researcher wants to compare findings across various clusters or market segments at a particular time to identify points of difference or similarities in performance or response patterns. Saunders *et al.* (2012:190) mention that the cross sectional study is a "snapshot" time horizon, as in this current study. Zikmund *et al.* (2013:195) assert that a cross sectional study is a study in which various segments of a population are sampled and data are collected at a single moment in time. The following section will focus on data collection methods employed in this study.

5.3 DATA COLLECTION METHODS

Two methods were used to distribute MS questionnaires to the respondents. Firstly, questionnaires were electronically distributed to the respondents using the Microsoft Outlook email system and secondly, the questionnaires were printed and physically distributed to respondents by the researcher. Completed MS questionnaires were all deposited into sealed boxes placed in a secure environment with security personnel and cameras. Respondents did have opportunity to ask the researcher questions on the objective, anonymity and the requirements of completing questionnaires. This offered the researcher opportunity to interact, clarify and answer questions and address concerns. The interaction between the researcher and the respondents, coupled with the timing of the research study (February 2014 – July 2014), contributed positively to the exceptionally high return rate as indicated in appendices L, M, N and O.

5.3.1 The MS questionnaires

Two different types of questionnaires were used, one for the Production Group and the other for the maintenance group: both questionnaires are based on the MS assessment tool. The questionnaires were compiled and used to gather, capture and record the MMS, PO and profitability data for this study. In Section 1.10.2.7 in Chapter 1, it was mentioned that the MS assessment tool would be utilised to conduct this study. Appendix C is the MS questionnaire for the Production Group, Appendix D is the MS questionnaire for the maintenance group, Appendix B is the information for the population demographics (designations or trades) and Appendix A is the invitation letter used in this study.

Tables 5.1 and 5.2 below provide a comparison of the original and the adapted statements. Appendices C and D indicate the application of the adapted statements as part of the MS questionnaires for the Maintenance and Production Groups respectively at the PetroSA GTL Refinery.

Table 5.1 Comparison of the original Maintenance Management Systems, assessment statements and the adapted MS statements applied in this study

Statement number	The original maintenance management system assessment statements	The MS adapted statements
1.0 Organisational Structure and Size		
1.1	The number of organisational levels is at the necessary minimum. Decisions can be made and carried out at the lowest appropriate level	Decisions can be made and carried out at the lowest appropriate level
1.2	Supervisors are not so overloaded with administrative and other duties that performance of their direct supervisory duties is harmed	Supervisors are not so overloaded with administrative or other duties that performance of their direct supervisory duties is hampered
1.3	There are sufficient cross trained mechanics and general helpers to balance craft workload	There are sufficient cross trained artisans, technicians and engineers to provide quality maintenance management service
1.4	Communication channels and procedures are designed for clear and quick transmission of information	Communication channels and procedures are designed for clear and quick transmission of information
1.5	Relationships with staff departments such as procurements, stores, engineers and accounting are clearly defined	Relationships with staff departments such as procurement, stores, finance and others are clearly defined
2.0 Computer Information and Support		
2.1	The MMS is computerised	The MMS is computerised
2.2	The right maintenance information is available to all levels of the organisation consistent with needs	The right maintenance information is available to all levels of the organisation
2.3	Information is complete and reliable	Information is complete and reliable
2.4	Monthly reports are promptly available relative to month-end	Monthly maintenance cost reports are compiled and readily available
2.5	Information and access to it, either online or in report format is timely	Information, data and history is accessible, retrievable and user friendly

Statement number	The original maintenance management system assessment statements	The MS adapted statements
3.0 Work/Job Planning		
3.1	Planning predicts the workload of each skill group in sufficient detail to permit early identification of pending shortfalls	Weekly and monthly look ahead plans are compiled, approved and communicated
3.2	Policy specifies how much detailed planning of selected maintenance work will be done. A target has been established	Policy specifies how detailed planning of selected maintenance work is done and a target has be established
3.3	The concept of maintenance planning is fully accepted by maintenance and operating	The concept of maintenance planning is fully accepted by maintenance supervisors
3.4	Planning procedures are well documented	Planning procedures are well documented
3.5	All shutdown work is pre-planned	All shutdown work is pre-planned
3.6	At least 90% of shutdown work is planned	Short and long term outage plans are compiled, approved and communicated
4.0 Maintenance Work Measurement		
4.1	Work standards or estimates for maintenance work are established by average or estimates	Weekly maintenance key performance indicators (KPIs) are compiled, issued and communicated
4.2	Work standards or estimates for maintenance work are established by historic averages	Monthly maintenance KPIs are compiled, issued and communicated
4.3	Work standards or estimates for maintenance work are established by analytical estimates	Visual planning boards are updated weekly
4.4	Standards or estimates are automatically posted to repetitive jobs by the computer	KPI trends are discussed bi-monthly, corrective and preventive measures devised and taken
4.5	Standards or estimates are pre-applied and feedback indicates a change of work scope adjustments are post applied	Capacity plans are compiled and issued weekly
4.6	Work measurement is a vital aspect of the management control process	Maintenance KPIs add value to improvement of MMS

Statement number	The original maintenance management system assessment statements	The MS adapted statements
5.0 Material Support and Control		
5.1	Usage records are employed to determine stock levels, order points and order quantities	Minimum and maximum /stock levels are defined or set
5.2	Cycle counting is used to pressure reliability of inventory records	Stock taking/cycle counting is used to preserve reliability of stock/inventory records
5.3	An intelligent part numbering system is utilised	An intelligent part numbering system is utilised
5.4	Usage records are employed to determine stock levels, order points and order quantities	Usage records are employed to determine stock levels, order points and order quantities
5.5	Maintenance, purchasing, accounting and the supply chain work together to assure availability of necessary parts, elimination of obsolete parts, adjustment of stock levels, minimal lost time by craftsmen etc.	Maintenance, procurement, finance and stores work together to assure availability of necessary parts, elimination of obsolete parts, adjustment of stock levels
6.0 Maintenance Scheduling and Coordination		
6.1	The system of work prioritisation effectively distinguishes between legitimate rush jobs and those which can be planned	The system of work prioritisation effectively distinguishes between legitimate rush jobs and those which can be planned
6.2	Scheduled jobs start, completion and crew assignments are published and distributed	Scheduled jobs start and completion dates, resource allocation and duration are published, distributed and communicated
6.3	Schedule compliance substantiated by the KPI report is high	Schedule compliance substantiated by KPI report is high
6.4	Schedule performance is measured and reported. Compliance and percentage of man-hours scheduled are calculated, analysed, plotted and reviewed	Planned and scheduled work is completed on time and substantiated by a KPI report

Statement number	The original maintenance management system assessment statements	The MS adapted statements
6.5	Procedures for requesting coordination and control of support services such as mobile equipment, rigging, transportation etc. are effective	Procedures for requesting, coordinating and controlling support services such as scaffolding; HP cleaning; rigging; cranes and workshops are effective

(Source: Adapted from Nyman *et al.* 2001:197-222)

Table 5.2 Comparison of the original production and profitability assessment statements and the adapted MS statements applied in this study

Statement Number	The original production and profitability assessment statements	The MS adapted statements
1.0 Production Perspective		
s1.1	Maintenance schedules are closely coordinated with production schedules and availability dates for repairs of production equipment are agreed upon in advance	Production plans and schedules are compiled, issued and communicated
s1.2	Shutdowns and other major projects are planned sufficiently in advance to permit allocation or procurement	Production volumes are reduced due to plant/equipment failure or breakdown
s1.3	Production scheduling and maintenance all contribute to adherence to PM schedule	Daily, weekly and monthly PO are within the scheduled or planned target
s1.4	Production planning is totally involved by scheduling production; they take advantage of product change-over	PO is planned and scheduled as per machine, plant or equipment capacity
s1.5	Scheduled provision made to take advantage of those windows and does not suffer	Machines, plant or equipment produce as per design capacity
s1.6	The maintenance organisation recognises and accepts accountability for meeting production schedules	Plant or equipment is always available after maintenance work is done on it
s1.7	Production and maintenance diligently work together towards high schedule compliance	Plant or equipment is always reliable after maintenance work is done on it
s1.8	Production and maintenance diligently work together towards high schedule compliance	Plant or equipment is always operable and efficient after maintenance work is done on it

Statement Number	The original production and profitability assessment statements	The MS adapted statements
2.0 Quality Perspectives		
s2.1	Are product defects reduced?	Manufactured products are within required specification
s2.2	Are customer complaints or claims attended to?	Product quality is consistent
s2.3	Are product defects identified?	Plant or equipment failure or breakdowns contribute to poor product quality and production delays
s2.4	Are product defects identified?	Plant or equipment availability and reliability contribute to poor product quality and production delays
s2.5	Are people trained on quality requirements and control?	Lack of skills, competencies and experience contribute to poor product quality and production delays
s2.6	Does the organisation document step-by-step procedures to do work?	Maintenance and production reworks contribute to production delays
3.0 Cost Perspective		
s3.1	Are costs of production captured and trended?	Product prices are reduced due to poor production quality
s3.2	Are costs of delivery captured and trended?	Sale or delivery of products to customers is delayed due to plant/equipment failure or breakdown
s3.3	Are costs of component, plant, equipment breakdowns captured, trended and reported?	Company loses income or revenue due to low production volumes
s3.4	Are costs of breakdown captured and trended?	Company loses income or money due to plant/equipment failure or breakdowns
s3.5	Are cost targets set, monitored and controlled?	Weekly, monthly and yearly income or revenue is within the set targets

Statement Number	The original production and profitability assessment statements	The MS adapted statements
s3.6	Are costs of quality captured, trended and reported?	Maintenance and production reworks contribute to the loss of production and revenue/income
4.0 Safety Perspective		
s4.1	Are statutory inspections done as per frequency?	There are no overdue RBI inspections for main equipment
s4.2	Are statutory inspections done as per frequency?	There are no overdue RBI inspections for PSVs
s4.3	Are statutory inspections done as per frequency?	There are no overdue RBI inspections for Pipeline (QPs)
s4.4	Are incidents reported, investigated and prevented?	There are no minor injuries in my area for the year 2014
s4.5	Are incidents reported, investigated and prevented?	There are no lost time injuries in my area for the year 2014
s4.6	Is the morale of employees improved to prevent sick leave and absenteeism?	The level of absenteeism is acceptable in my area
5.0 Environmental Perspective		
s5.1	Are hazardous chemical spillages reported and prevented?	There is no product major spillage in my area for the year 2014
s5.2	Are hazardous chemical spillages reported and prevented?	There is no product minor spillage in my area for the year 2014
s5.3	Are hazardous chemical spillages reported and prevented?	There are no priority 1 overdue incidents for production plant or equipment
6.0 Learning and Growth Perspective		
s6.1	What training interventions have been determined for manpower?	There are sufficient cross trained artisans to balance work load in my area
s6.2	Is a skills audit being done to determine skills gaps?	There are sufficient cross trained operators to balance work load in my area

Statement Number	The original production and profitability assessment statements	The MS adapted statements
s6.3	Does the organisation support manpower individual development plan training?	There are sufficient cross trained technicians to balance work load in my area
s6.4	Does the organisation have a manpower skills matrix to record experience and training needs?	There are sufficient cross trained engineers to balance work load in my area
s6.5	Does the organisation perform refresher training?	There are sufficient cross trained supervisors to balance work load in my area
s6.6	Does the organisation perform on the job training?	There are sufficient cross trained inspectors to balance work load in my area

(Source: Adapted from Nyman *et al.,* 2001: 197-222 & Mather. 2005:121-129)

The following section will focus on the generation of questionnaire scales and the reliability and validity of the MS questionnaire.

5.3.1.1 Generation of questionnaire scales

The responses were captured on a five-point scale with response statements indicating whether the respondent agrees or is neutral or disagrees with each statement. The responses ranged from 1 to 5 and the scales on MS questionnaires were displayed as follows:

1 = strongly disagree
2 = disagree
3 = neutral
4 = agree
5 = strongly agree

The data from the MS questionnaires were used in the analysis of the impact of the MMS on PO and profitability of the PetroSA GTL Refinery.

5.3.1.2 Reliability of MS questionnaires

According to Hair *et al*. (2011:456), reliability is associated with the term "consistency" and a survey instrument is reliable if its' repeated use results in consistent responses from samples with similar demographic characteristics. Reliability refers to the statistical likelihood that repeating the data collection exercise will produce similar, if not identical results (Cameron and Price, 2009: XXVII). Saunders *et al*. (2012:192) agree that reliability refers to the extent to which a data collection technique will yield consistent findings, similar observations would be made or conclusions reached by other researchers or there is transparency in how sense was made from the raw data. In support of this, Page *et al*. (2003:332) concur that reliability pertains to the results that are achieved when the research instrument provides identical repeated measures relating to some constant factor, or can be said to be internally consistent. The table below displays the possible threats to reliable data collection and analysis.

Table 5.3 Threats to reliability

Threat	Definition and explanation	Action taken for this research study
Participation error	Any factor which adversely alters the way in which a participant performs e.g. lunch breaks	Researcher – participant interaction played a positive role in ensuring that quality time is given or taken for completing and submitting questionnaires
Participation bias	Any factor which includes a false response like an open space office setup for participants	Researcher – participant interaction was a one-on-one relationship
Researcher error	Any factor which alters the researcher's interpretation, like being tired, weariness	Researcher planned and scheduled milestones to ensure that this study was done and completed on a more realistic duration
Researcher bias	Any factor which includes bias in the researcher's recording of responses like a subjective view and disposition	Researcher used data and information provided by questionnaires as completed and submitted by respondents. Researcher did not add or remove anything

(Source: Adapted from Saunders *et al.,* 2012:192)

5.3.1.3 Validity of MS questionnaires

According to Cameron and Price (2009:216), validity of a measure or indicator is the extent to which it measures what it purports to measure, that is, if it does not do what it says on the tin, conclusions based on that data may be similarly invalid and irrelevant and/or misleading. Hair *et al*. (2011:238) contend that validity is the extent to which a construct measures what it is supposed to measure. In support of this, Saunders *et al*. (2012:684) mention that validity is the extent to which a data collection method or methods accurately measure what they were intended to measure and it is the extent to which research findings are really about what they profess to be about. Zikmund *et al*. (2013:303) confirm that validity is the accuracy of a measure or the extent to which a score truthfully represents a concept.

5.3.2 The MS survey

The study focussed on the PetroSA GTL Refinery situated in Mossel Bay in the Western Cape. As stated in Section 1.2 in Chapter 1, the PetroSA GTL Refinery consists of six maintenance and production areas, namely AGS, RFM, SNT, REF, B&S and O&U. The Refinery has a total of 140 maintenance and 96 production employees (based on the 2013 organisational structure). This afforded the researcher an opportunity to gain a representative view of maintenance and production employee experiences at the Refinery.

According to Cameron and Price (2009:224), a population is a group from which the sample is drawn. Hair *et al.* (2011:454) state that a population is the total number of elements sharing a set of characteristics relevant to the research project. Saunders *et al*. (2102:678) concur and point out that a population is a complete set of cases or group members. Zikmund *et al.* (2013:385) conclude that a population is a complete group of entities that share some common sets of characteristics. Thus, the population of the study for this survey comprised maintenance artisans, technicians, superintendents, engineers, planners and managers forming the maintenance group population at the PetroSA GTL Refinery. The reason for selecting the PetroSA GTL Refinery over other sites (Orca, Logistics base, FA Platform and head office) is based on various factors, which include, but are not limited to, the following:

- it has the largest number of maintenance employees (140);
- it has the largest number of machines and equipment where maintenance takes place;
- it is the core business area, where maintenance and production take place;
- it is expected by law that the PetroSA GTL refinery complies with statutory and regulatory requirements to operate plant, equipment and machinery based on the design and operating pressure parameters that depend on plant, equipment and machinery reliability, availability, operability and maintainability and

- the vice president of the operations group welcomed this study and approved the use of company data and information.

For the purpose of the MMS, PO and profitability survey, the units of investigation consisted of the six areas at the PetroSA GTL Refinery where maintenance and production take place. The areas as mentioned above are AGS, RFM, SNT, REF, B&S and O&U while the units of analysis for MMS were the maintenance employees according to designation (artisans, technicians, superintendents, engineers, planners and manager). For PO and profitability the units of analysis were production employees (process controllers, supervisors, superintendents, specialists and managers). According to Zikmund *et al.* (2013:392), several alternative ways to take a sample are available; the main alternative plans are the probability and non-probability techniques. The authors state that the probability sampling technique is a technique in which every member of the population has a known, non-zero probability of selection. This implies that in probability sampling it can be specified in advance that a percentage of each segment of population will be in the sample. This is the main attribute and characteristic that sets probability sampling and makes probability sampling technique a preferred sampling technique for this study.

Adding to this, Zikmund *et al.* (2013:392) claim that non-probability sampling is the technique in which units of the sample are selected on a basis of personal judgement or convenience: the probability of any particular member of the population being chosen is unknown. This study followed a probability sampling technique approach. According to Zikmund *et al.* (2013:396), the probability sampling techniques include the following:

- Simple random sampling: this is the sampling procedure that assures each element in the population of an equal chance of being included in the sample.
- Systematic sampling: this is the sampling procedure in which a starting point is selected by a random process and then every nth number on the list is selected.
- Stratified sampling: this is the sampling procedure in which simple random sub-samples that are more or less equal on some characteristic are drawn from within each stratum of the population.

- Cluster sampling: this is an economically efficient sampling technique in which the primary sampling unit is not the individual element in the population but a large cluster of elements; clusters are selected randomly.
- Multi-stage sampling: this is the sampling technique that involves using a combination of two or more probability sampling techniques.

The stratified sampling technique approach was followed in this study to obtain a more efficient sample than there would be when following or using the other sampling techniques. According to Zikmund *et al.* (2013:397), a stratified sampling technique includes the following:

- proportional stratified sampling technique: this is a stratified sampling technique in which the number of sampling units drawn from each stratum is in proportion to the population size of that stratum and
- disproportional stratified sampling technique: this is a stratified sampling technique in which the sample size for each stratum is allocated according to analytical consideration.

The proportional stratified sampling technique was used to select the target population (ideal number of respondents) to participate in both the maintenance management system and the production and profitability surveys.

For the purpose of this study, the population was segmented according to:

- the Maintenance and Production Groups;
- six production and maintenance areas (AGS, RFM, SNT, REF, B&S and O&U) and
- designations or trades (Maintenance group: artisans, technicians; superintendents; supervisors; planners; engineers and managers. Production Group: process controllers; specialists; supervisors; superintendents and managers).

Each stratum is in proportion to its size in the overall population: in this case, 40% of 140 maintenance employees and 40% of 96 production employees. A random sample was drawn from each stratum. Table 5.4 indicates the advantages and disadvantages of the simple random, systematic random, stratified, cluster and multi-stage sampling techniques respectively.

Table 5.4 Comparison of stratified sampling techniques and probability samples

Item No	Sampling technique	Advantages	Disadvantages
1.0	Simple random	Only minimal advance knowledge of population needed Easy to analyse data and compute error	Requires sampling frame to work from Does not use knowledge of population that researcher may have Larger error for same sampling size than in stratified sampling Respondents may be widely dispersed and may result in high costs
2.0	Systematic	Simple to draw sample Easy to check	If sampling interval is related to periodic ordering of the population it may introduce increased variability
3.0	Stratified	Ensures representation of all groups in the sample Characteristics of each stratum can be estimated and comparison made Reduces variability for same sample size	Requires accurate information in proportion to each stratum If stratified lists are not already available, they can be costly to prepare
4.0	Cluster	If cluster is geographically defined, it yields	Larger error for comparable sizes than with other

Item No	Sampling technique	Advantages	Disadvantages
		lowest field cost Requires listing of all clusters but of individuals only within clusters Can estimate characteristics of clusters as well as of population	probability samples Researcher must be able to assign population members to unique cluster or else duplication or omission of individuals will result
5.0	Multi-stage	Depends on combined techniques	Depends on combined techniques

(Source: Zikmund, 2013:402)

In line with Table 5.4 above, Page *et al.* (2003), Cameron and Price (2009), Welman *et al.* (2011), Hair *et al.* (2011) and Saunders *et al.* (2012) concur and state that in a stratified sampling technique all groups in a sample have an equal probability of being selected and/or represented. The MS assessment tool was used to collect data for the MMS, PO and profitability. As stated above, the study consists of two research population groups, the Maintenance and Production Groups. Each group represents the actual number of respondents or population of the MMS, PO and profitability surveys. The Maintenance group consisted of 140 maintenance employees as indicated in Table 5.5 below (N = 140 and n=56 40%). The Production Group consisted of 96 production employees as shown in Table 5.6 below (N = 96 and n=38, 40%). Although the number of realised respondents corresponds with the target population, the proportions of the various areas differ.

The respondents (Maintenance and Production Groups) evaluated both the MMS, PO and profitability on a Likert Scale of 1 to 5 in terms of their perception and the expectation of the status of the MMS, PO and profitability of the PetroSA GTL Refinery. According to Zikmund *et al.* (2013:316), a Likert Scale is a measure of attitudes designed to allow respondents to rate how strongly they agree or disagree with carefully constructed statements, ranging from very positive to very negative attitudes towards some object. The authors further elaborate that the number of alternatives may range from three to ten or more. In this study, a five-point scale was used. The MS assessment tool consisted of six dimensions or perspectives, namely production, quality, cost, safety, environment, learning and growth. In order to optimise feedback, the participants had sufficient exposure to MMS, PO and profitability optimisation processes at the PetroSA GTL Refinery to provide meaningful feedback on their perception and expectations of the status of the MMS, PO and profitability at the Refinery. As mentioned previously, the MS questionnaires were distributed electronically and manually to the respondents using the Microsoft Outlook email system. Participants completed the questionnaires during their breaks and/or lunchtime. Questionnaires took approximately 15 minutes to complete.

Table 5.5 Response by maintenance group

Area	**Artisan**	**Planner**	**Supervisor**	**Technician**	**Engineer**	**Manager**	**Frequency**	**%**	**Cumulative %**
AGS	3	1	1	1	1	1	**8**	**14%**	
RFM	4	1	1	0	1	1	**8**	**14%**	**14%**
SNT	2	1	1	2	2	1	**9**	**16%**	**29%**
REF	4	2	4	0	2	1	**13**	**23%**	**45%**
B&S	3	1	1	1	1	1	**8**	**14%**	**68%**
O&U	4	1	2	1	1	1	**10**	**18%**	**82%**
Total	**20**	**7**	**10**	**5**	**8**	**6**	**56**		**100%**

Table 5.6 Response by Production Group

Area	**Process Controllers**	**Supervisor**	**Specialist**	**Engineer**	**Manager**	**Frequency**	**%**	**Cumulative %**
AGS	2	2	1	1	1	**7**	**18%**	
RFM	1	1	1	1	1	**5**	**13%**	**18%**
SNT	2	1	1	3	1	**8**	**21%**	**32%**
REF	2	1	2	2	1	**8**	**21%**	**53%**
B&S	1	1	1	1	1	**5**	**13%**	**74%**
O&U	1	1	1	1	1	**5**	**13%**	**87%**
Total	**9**	**7**	**7**	**9**	**6**	**38**		**100%**

5.3.3 Pre-testing

According to Hair *et al.* (2011:267), no questionnaire should be administered before the researcher has evaluated the likely accuracy and consistency of the responses. The authors further state that pre-testing is carried out using a small sample of respondents with characteristics similar to those of the target population. The MS assessment tool was pre-tested on respondents who fitted the profile of the PetroSA GTL Refinery maintenance and production population groups. Maintenance and production employees, including management, were part of the pilot project to pre-test MS questionnaires.

The pre-test was done to ensure that the MS assessment tool was understandable, which would increase the reliability of the data collected. The pre-test was conducted during February and March 2014.

5.4 DATA ANALYSIS

Microsoft Excel 2010 data analysing tools were used to perform and calculate all statistical procedures. Data were analysed by means of the Cronbach's Alpha as a measure of internal consistency. The means, standard deviations, gap analysis, the Pearson product moment correlation coefficient (r) and the coefficient of determination (R^2) are the descriptive statistical procedures used to analyse data and measure internal consistency. The reliability of perception and expectation dimensions of the MS assessment tool were calculated using the Cronbach's Alpha. The validity and reliability of the MS questionnaires will be discussed in Section 5.5 of this study.

According to Saunders *et al.* (2012:502), descriptive statistics enables a researcher to describe and compare variables numerically. In support of this, Zikmund *et al.* (2013:410) state that descriptive statistics describe the characteristics of the population or sample. According to Hair *et al.* (2011:150), descriptive statistics include rankings (best to worst), frequency (how many) and cross-classifications (comparisons of frequencies, group means, correlations and predictions using regression). Means and standard deviations were the descriptive statistics used in this study, based on the quantitative responses obtained from the MS questionnaires.

According to Saunders *et al.* (2012:674-682), the mean is the average value calculated by adding up the values of each case for a variable and dividing by the total number of cases and the standard deviation is a statistical measure that describes the extent of spread of data values around the mean for a variable containing numerical data. Appendices E and V indicate the means and standard deviations for the combined areas and Appendices F, G, H, I, J, K, P, Q, R, S, T and U indicate means and standard deviations per area.

A gap analysis was performed on all means per area and for the overall average means for the combined areas for the Maintenance and Production Groups. In addition, the Pearson product moment correlation (r) was used to measure the relationship between the MMS, PO and profitability at the PetroSA GTL Refinery for all six areas. The coefficient of determination (R squared) was also used to calculate the proportion of variance. According to Hair *et al.* (2011:352), the Pearson product moment correlation (r) measures the linear association between two metric variables. It ranges from -1.00 to +1.00 with 0 representing absolutely no association between the two metric variables. It is a statistical test that assesses the strength of the relationship between two numerical data variables (Saunders *et al.*, 2012:677).

According to Cameron and Price (2009:XVII), correlation is the degree of association between two sets of measures. Hair *et al.* (2011:351) highlight that the values of +_0.91 and 1.00 are considered a very strong correlation. Table 5.7 depicts the values of thumb about correlation coefficient sizes.

Table 5.7 Values of thumb about correlation coefficient sizes

Coefficient range	Strength of association
±0.91-1.00	Very strong
±0.71-0.90	High
±0.41-0.70	Moderate
±0.21-0.40	Small, but definite relationship
±0.00-0.20	Slight, almost negligible

(Source: Hair *et al.* 2011:351)

The coefficient of determination (R^2) ranges from 0.00 to 1.00 and represents the amount of variation explained or accounted for one variable by the other (Hair *et al.*, 2011:353). Saunders *et al.* (2012:680) state that the coefficient of determination or the regression coefficient ranges between 0.00 and +1.00 and enables the strength of the relationship between a numerical dependent variable and a numerical independent variable to be assessed. It represents the proportion of the variation in the dependent variable that can be explained statistically by the independent variable. The value of 1.00 means that all the variation in the dependent variable can be explained statistically by the independent variable. A value of 0.00 means that none of the variation in the dependent variable can be explained by the independent variable. The coefficient of determination measures the proportion of the variation in a dependent variable (PO and profitability) in this study that can be explained statistically by the independent variable (MMS).

5.5 RESEARCH QUALITY

There are three criteria for determining the quality or good measurement of an indicator and these are reliability, validity and sensitivity. According to Welman *et al.* (2001:139), reliability is the extent to which the obtained scores may be generalised to different measuring occasions, measurement or test forms and measurement or test administrators. Page *et al.* (2003:322) contend that reliability refers to the results achieved when the research instrument provides identical repeated measures relating to some constant factor or can be said to be internally consistent. Saunders *et al.* (2012:192) support this and state that reliability refers to whether data collection techniques and analytic procedures would produce consistent findings if they were repeated on another occasion or if they were replicated by a different researcher. Adding to this, Zikmund *et al.* (2013:301) describe reliability as an indicator of a measure’s internal consistency. Table 5.8 below provides reliability estimates as identified by Zikmund *et al.* (2013:302).

Table 5.8 Reliability estimates

Type	Coefficient	What it measures
Coefficient alpha (also known as Cronbach's Alpha)	Internal consistency	Computes the average of all possible split half reliabilities for a multiple item scale
Test-retest reliability	Stability	Repeatedly measures same respondents or group of respondents using the same measurement device and under similar conditions using correlation coefficient. It administers the same scale or measure to the same respondent at two separate points in time
The split half reliability	Internal consistency	Group of scale items that are divided in half and correlated as two sets of items. High correlation between two halves indicates high reliability

(Source: Hair *et al.,* 2011:234 and Zikmund *et al.,* 2013:302)

To back up and support the information provided by Hair *et al.* (2011:234) and Zikmund *et al.* (2013:302) in Table 5.8 above, Hair *et al.* (2011:235) further mention that the Cronbach's Alpha is also known as the coefficient alpha and measures internal consistency reliability. It ranges in value from 0.00, meaning that no consistency exists and 1.00, meaning that there is complete consistency in all items, yields and corresponding values. The following rule of thumb in Table 5.9 has been adopted to be used in this study.

Table 5.9 Rule of thumb about Cronbach's Alpha coefficient sizes

Cronbach's Alpha coefficient range	Strength of association
<0.6	Poor
0.6 to <0.7	Moderate
0.7 to <0.8	Good
0.8 to <0.9	Very good
>0.9	Excellent

(Source: Hair *et al.*, 2011:235)

It should be noted that the alpha of 0.7 to 08 indicated in Table 5.9 above, as “good” internal consistency reliability is a reasonable goal. As mentioned in the previous pages, validity is another criterion for measuring good quality, therefore, according to Cameron and Price (2009:216), a measure or indicator is valid if it measures what it purports to measure. Adding to this, Hair *et al.* (2011:460) state that validity is an accurate measurement of a concept or construct. Saunders *et al.* (2012:684) assert that validity is the extent to which research findings are about what they profess to be about. In support of this, Zikmund *et al.* (2013:303) maintain that validity is the accuracy of a measure or the extent to which a score truthfully represents a concept. Table 5.10 depicts three forms of validity that are used to establish the authenticity of an assessment tool.

Table 5.10 Forms of validity

Form of validity	**What it is?**	**How is it established?**
Content validity	Is the degree that a measure covers the breadth of the domain interest	Involves subject matter experts to determine if items assess what the researcher want to research
Criterion validity	The ability of a measure to correlate with other standard measures of similar constructs or established criterion	Selects criteria or criterion and correlates scope
Construct validity	Exists when a measure reliably measures and trustfully represents a unique concept	Assesses the construct and correlates scores

(Source: Zikmund *et al.*, 2013:304)

According to the results from the MS questionnaires, it has been proven that the MS assessment tool is reliable and valid. The third criteria for measuring the quality of an indicator is sensitivity. According to Saunders *et al.* (2012:681), sensitivity refers to the level of concern on the part of a potential host organisation, information and participants or respondents about the nature of a research project and the use of data that will affect willingness to cooperate. Adding to this, Zikmund *et al.* (2013:305) state that sensitivity is the ability of the measurement instrument to accurately measure variability in stimuli or responses. As mentioned above, the two criteria (reliability and validity) were tested and the assessment tool is deemed reliable and valid. The next section of this chapter will focus on delimitations.

5.6 DELIMITATIONS

According to the dictionary unit of South African English (2009:307) “delimit” refers to “determining the limits or boundaries of a thing or project”. In this study, data were collected from all six areas of the PetroSA GTL Refinery namely AGS, RFM, SNT, REF, B&S and O&U. The Head Office, Orca, Logistics Base and FA Platform were excluded from the study. Further research will be required to determine whether the findings of this study could be extended and made applicable to Head Office, Orca, Logistics Base and FA Platform.

5.7 RESEARCH ETHICS

Research ethics, according to Cameron and Price (2009:XXVIII), is a code of practice that determines what is and what is not acceptable research practice. Mouton (2011:238) contends and states that ethics of science concerns what is wrong and what is right in conducting the research study. Adding to this, Saunders *et al.* (2012:226) concur and point-out that research ethics refers to the standards of the researcher’s behaviour in relation to the rights of those who become the subjects of a research project or who are affected by it. Saunders *et al.* (2012:231) highlight the following ethical principles and rationale for conducting the research project (Table 5.1).

Table 5.11 Ethical principles and rationale of conducting a research project

Item No	Ethical Principle	Ethical rationale
1.	Integrity and objectivity of the researcher	The quality of a research study depends on the integrity and objectivity of the researcher
2.	Respect for others	A researcher's position is based on the development of trust and respect
3.	Avoidance of harm	Any harm to participants must be avoided
4.	Privacy of those taking part	Privacy is a key principle that links to or underpins several other principles considered in a study
5.	Voluntary nature of participation and right to withdraw	The right not to participate in a research project is unchallengeable
6.	Informed consent of those taking part	Researcher to provide sufficient information and assurances to those taking part

(Source: Adapted from Saunders *et al.*, 2012:231)

Every effort was made to adhere to and comply with all the six principles and rationale as stated above during the duration of this study. The research proposal for this study was submitted to the ethics committee of UNISA College of Management through the supervisor for approval. A written consent or approval was issued and permission granted to the researcher by the ethics committee. The researcher was also given a written permission by PetroSA management to utilise company data and information for this research project.

The purpose of this study was clearly explained to the participants so that they understood the requirements, nature of the study and possible impact on them and the organisation. Participants/respondents remained anonymous during the course of this study and had the right to ask questions and request copies of findings. Care was taken not to misrepresent the findings in order to meet the intended purpose of the study. Questionnaires were developed based on questions and requirements of the MS assessment tool. No permission was required from the publishers because questionnaires were re-designed to be different from the original ones.

5.8 CHAPTER SUMMARY

A quantitative approach was used in this study. A study of MMS, PO and profitability was conducted by means of reliable and valid measuring and/or assessment tool namely the MMS questionnaires. Chapter 5 elaborated on the research design and methodology to investigate the impact of the MMS on PO and profitability at the PetroSA GTL Refinery. The chapter deliberated on and addressed the research strategy or philosophy adopted, data collection methods, data analysis, research quality, delimitations and research ethics.

The objective of this chapter was to determine the impact of the MMS on PO and profitability at the PetroSA GTL Refinery by calculating the correlation between the means, Cronbach's Alpha, Pearson's product moment correlation (r) and coefficient of determinants (R^2) of the perceptions versus expectations of both the Maintenance and Production Groups as per the collected data on the questionnaires. This will be elaborated on chapters 6 and 7.

Chapter 6 discusses the analysis of the data from the MS questionnaires.

Chapter 6: FINDINGS

6.1 INTRODUCTION

Chapter 1 stated that the primary objective of this study was to investigate the impact of the maintenance management system (MMS) on production output (PO) and profitability at the PetroSA GTL Refinery. Chapters 2, 3 and 4 unpacked the literature review for the study with the emphasis on the MMS, PO and profitability/profit. In Chapter 5, the research design and methodology were introduced and explained. Chapter 6 deals with the empirical findings of the research design and methodology as discussed in Chapter 5, in order to address the research objectives for this study

This chapter introduces, discusses and explains the reliability of the analysis of the Maintenance Scorecard (MS) assessment tool, descriptive statistics and the participant's designations during the year of this study. The PO and profitability perceptions versus expectations also form part of this chapter. A detailed PO and profitability gap analysis per area and for the PetroSA GTL Refinery as a whole will then be conducted. The chapter further focuses on the calculation of the means and standard deviations as well as the correlation analysis between the MMS, PO and profitability of the PetroSA GTL Refinery. The strength of the linear relationship between these three constructs (MMS, PO and profitability) is explained by means of a Pearson's product moment correlation coefficient and the coefficient of determination.

The main sections of this chapter are depicted in Figure 6.1 below.

CHAPTER 6: FINDINGS

6.1 INTRODUCTION

6.2 RELIABILITY ANALYSIS

6.3 DESCRIPTIVE STATISTICS

6.3.1 Participants designations

6.3.2 Production output (PO) and profitability perceptions versus perceptions for the Production Group

6.3.3 PO and profitability perceptions versus perceptions for the Maintenance Group

6.3.4 PO and profitability perceptions versus expectations for all combined areas (Overall)

6.4 THE MANAGEMENT SCORECARD (MS) GAP ANALYSIS

6.4.1 Gap analysis: Air and Gas Separation (AGS)

6.4.2 Gap analysis: Reforming (RFM)

6.4.3 Gap analysis: Synthol (SNT)

6.4.4 Gap analysis: Refinery (REF)

6.4.5 Gap analysis: Blending and Storage (B&S)

6.4.6 Gap analysis: Offsites and Utilities (O&U)

6.4.7 Gap analysis: All areas combined (Overall)

6.5 THE MS MEANS AND STANDARD DEVIATIONS

6.6 CORRELATION ANALYSIS

6.7 CHAPTER SUMMARY

Figure 6.1 Layout of Chapter 6

6.2 RELIABILITY ANALYSIS

As stated in section 5.3.1.2 (Chapter 5), reliability is the extent to which a data collection technique will yield consistent findings and similar observations would be made or conclusions would be reached by other researchers, or that there is transparency in how sense was made from the raw data. Reliability is synonymous with "consistent", "reliable" and "identical" results produced by a tool (Cameron and Price, 2009; Hair *et al.*, 2011; Page *et al.*, 2003 and Saunders *et al.*, 2012). In addition, Hair *et al.* (2011) mention that Cronbach's Alpha measures the internal consistency of a set of items comprising a scale. The closer the Cronbach's Alpha to 1.0, the greater the internal consistency of the items in the scale will be.

Tables 6.1 and 6.2 below represent the Cronbach's Alpha coefficient for both the perception and expectation dimensions of the MS questionnaires for the Production Group, while Tables 6.3 and 6.4 indicate the Cronbach's Alpha coefficient for both the perception and expectation dimensions of the MS questionnaires for the Maintenance Group.

Table 6.1 Reliability statistics for perception dimensions for the Production Group

Dimension	Cronbach's Alpha	Number of items
Production Perspective ("Asset health gap")	**0.7926**	**8**
Quality Perspective ("Reliability and quality gap")	**0.7485**	**6**
Cost Perspective ("Asset provision gap")	**0.7399**	**6**
Safety Perspective ("Asset prioritisation gap")	**0.7934**	**6**
Environmental Perspective ("Asset performance gap")	**0.6293**	**3**
Learning and growth Perspective ("Skills and working conditions gap")	**0.8588**	**6**
Overall	**0.8039**	**35**

Table 6.2 Reliability statistics for expectation dimensions for the Production Group

Dimension	Cronbach's Alpha	Number of items
Production Perspective (“Asset health gap”)	**0.8111**	**8**
Quality Perspective (“Reliability and quality gap”)	**0.6803**	**6**
Cost Perspective (“Asset provision gap”)	**0.7466**	**6**
Safety Perspective (“Asset prioritisation gap”)	**0.8841**	**6**
Environmental Perspective (“Asset performance gap”)	**0.7250**	**3**
Learning and growth Perspective (“Skills and working conditions gap”)	**0.6746**	**6**
Overall	**0.7643**	**35**

Table 6.3 Reliability statistics for perception dimensions for the Maintenance Group

Dimension	Cronbach's Alpha	Number of items
Production Perspective (“Asset health gap”)	**0.7197**	**5**
Quality Perspective (“Reliability and quality gap”)	**0.7356**	**5**
Cost Perspective (“Asset provision gap”)	**0.7853**	**6**
Safety Perspective (“Asset prioritisation gap”)	**0.8808**	**6**
Environmental Perspective (“Asset performance gap”)	**0.8448**	**5**
Learning and growth Perspective (“Skills and working conditions gap”)	**0.8676**	**5**
Overall	**0.9372**	**32**

Table 6.4 Reliability statistics for expectation dimensions for the Maintenance Group

Dimension	Cronbach's Alpha	Number of items
Production Perspective ("Asset health gap")	**0.8085**	**5**
Quality Perspective ("Reliability and quality gap")	**0.8565**	**5**
Cost Perspective ("Asset provision gap")	**0.8576**	**6**
Safety Perspective ("Asset prioritisation gap")	**0.9171**	**6**
Environmental Perspective ("Asset performance gap")	**0.8378**	**5**
Learning and growth Perspective ("Skills and working conditions gap")	**0.8192**	**5**
Overall	**0.9551**	**32**

The Cronbach's Alpha coefficient values for the Maintenance Group MS questionnaires (Tables 6.3 and 6.4) indicate that both the perception and expectation dimensions are within the acceptable internal consistency. The Cronbach's Alpha coefficient values for the Production Group MS questionnaires represent the following: Table 6.1 indicates that five dimensions on the perception are within the acceptable consistency while one indicated moderate internal consistency. Table 6.2 indicates that four dimensions on the expectations are within the acceptable internal consistency, whilst two indicated moderate internal consistency. All dimensions on overall ratings indicated acceptable to high internal consistency.

Considering the rule of thumb proposed by Hair *et al.* (2011:235) and in Table 5.9 in Chapter 5, the reliability for the MS assessment tool can be described as varying between "moderate" and "excellent".

6.3 DESCRIPTIVE STATISTICS

According to Hair *et al.* (2011:150), descriptive statistics include rankings showing the best or worst, frequencies indicating how many items, cross-classifications displaying comparisons of frequencies, Group means, correlations and predictions using regression. The sections below describe the participants' designations during the researcher’s year of study. The MMS, PO and profitability perception versus expectation per area is also included.

6.3.1 Participant’s designations

Figure 6.2 displays the distribution of participants among various trades and designations across all six maintenance and production areas at PetroSA GTL Refinery.

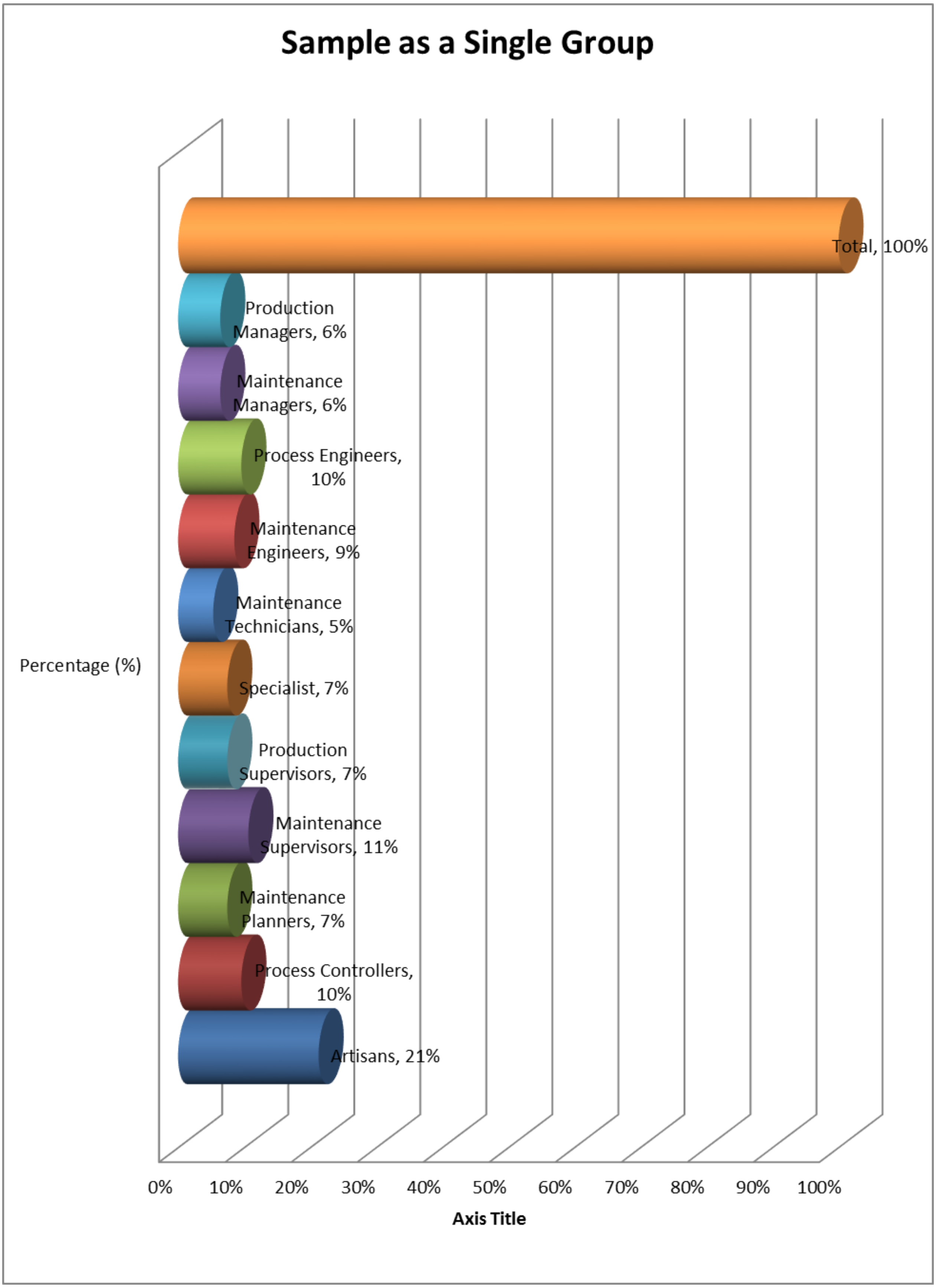

Figure 6.2 Respondents by designation

As shown in Figure 6.2 above, the largest group of respondents or participants are artisans that are tasked to execute maintenance and asset management in order to implement the MMS. The process controllers are the next largest group, followed by engineers, this group is tasked to enhance PO that in turn affects profitability.

6.3.2 Production Output (PO) and profitability perceptions versus expectations for the Production Group

Figure 6.3 below shows that for all six areas, on average, expectations were consistently higher than perceptions. This is supported by the information in appendices F, G, H, I, J and K. The information in appendices L and M indicates the proportions of respondents who selected different ratings (1 to 5) to indicate how high their perceptions and expectations were regarding the different aspects of the different dimensions of the PO and profitability.

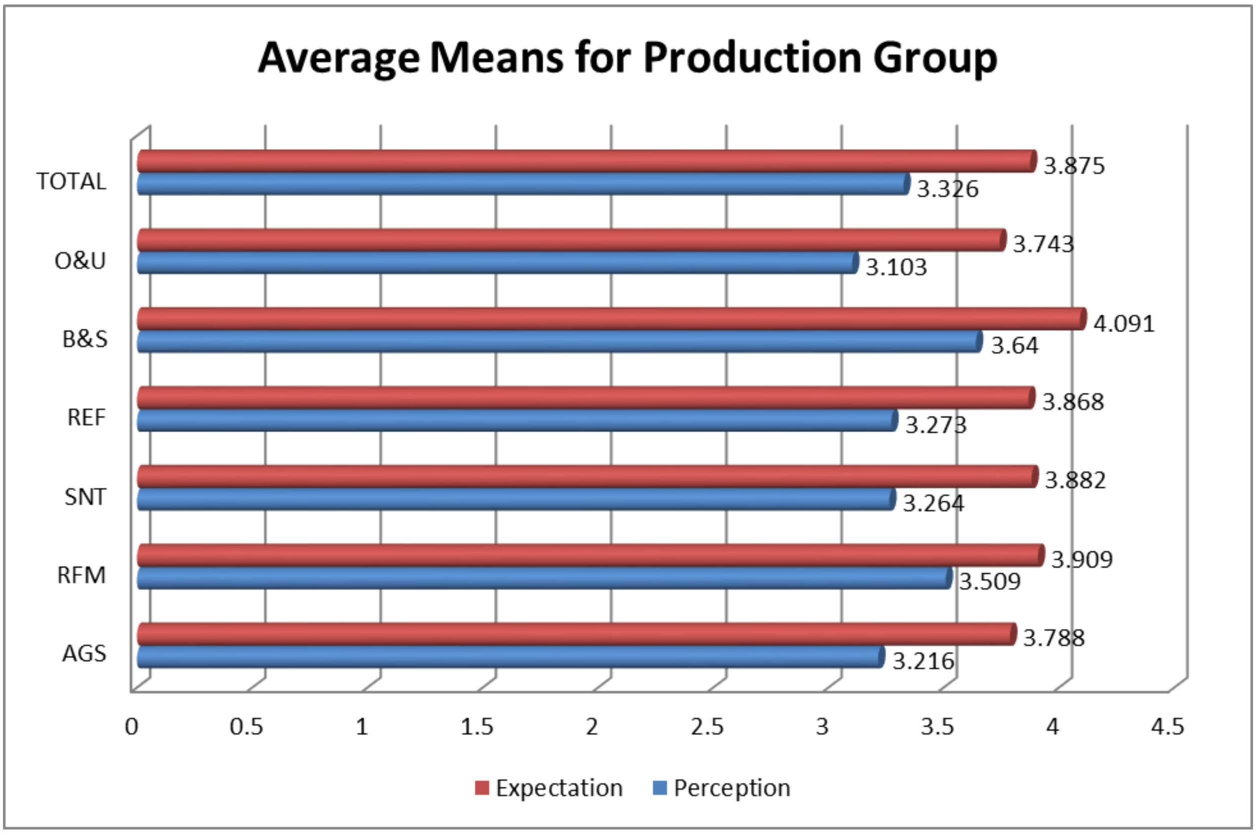

Figure 6.3 PO and profitability perceptions versus expectations for the Production Group

It is evident from Figure 6.3 that for all six areas, the level of PO and profitability was lower than the respondents' expectations.

6.3.3 PO and profitability perceptions versus expectations for the Maintenance Group

Figure 6.4 below shows that for all six areas, on average, the expectations were consistently higher than the perceptions. This is supported by the information in appendices P, Q, R, S, T and U. The information in appendices N and O indicates the proportions of respondents who selected different ratings (1 to 5) to indicate how high their perceptions and expectations were regarding the different aspects of the different dimensions of PO and profitability.

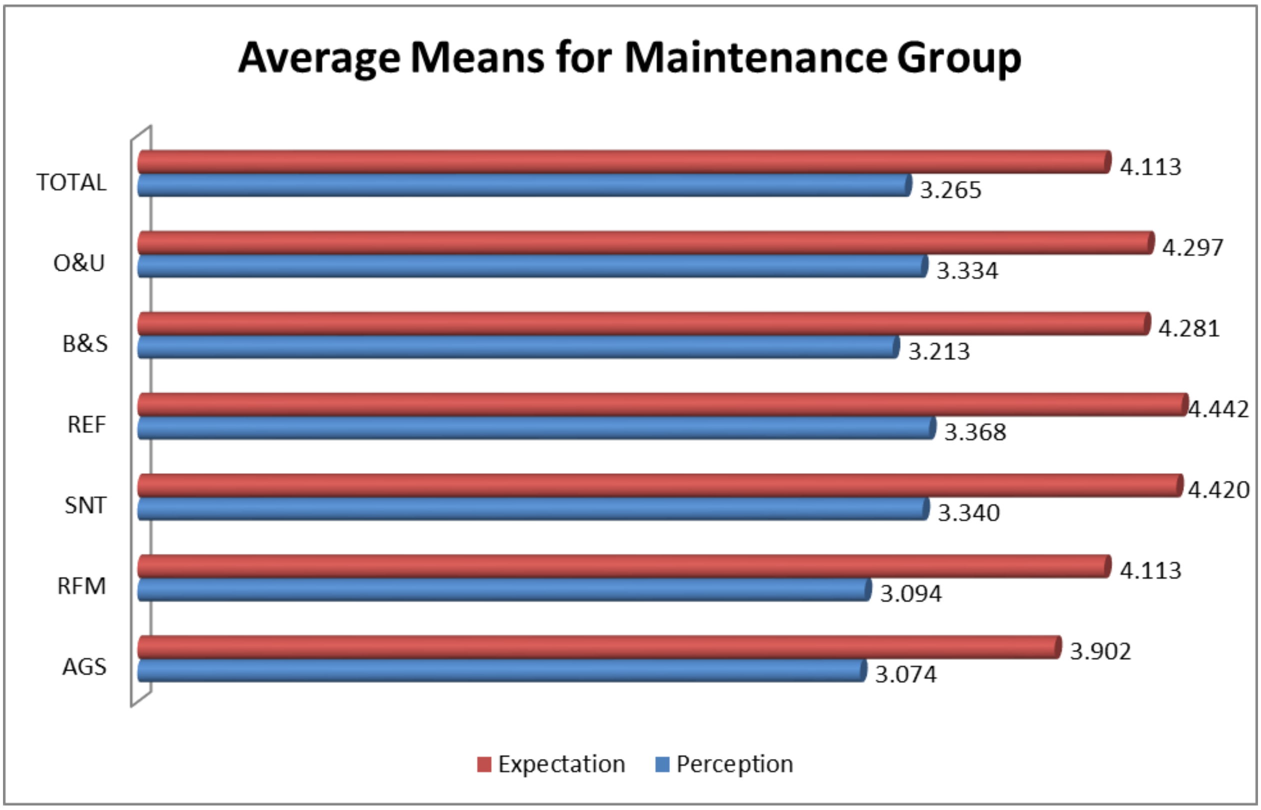

Figure 6.4 PO and profitability perception versus expectations for the Maintenance Group

6.3.4 PO and profitability perceptions versus expectations for all combined areas

It is evident from Figure 6.5 that for all six areas, the level of MMS was lower than the respondents' expectations. For the Production Group, Reforming (RFM) represents the smallest PO&P gap of -0.406 while Offsites and Utilities (O&U) represents the largest PO&P gap of -0.653. For the Maintenance Group, Air and Gas Separation (AGS) represents the smallest PO&P gap of -0.828 while Synthol (SNT) represents the largest PO&P gap of -1.080.

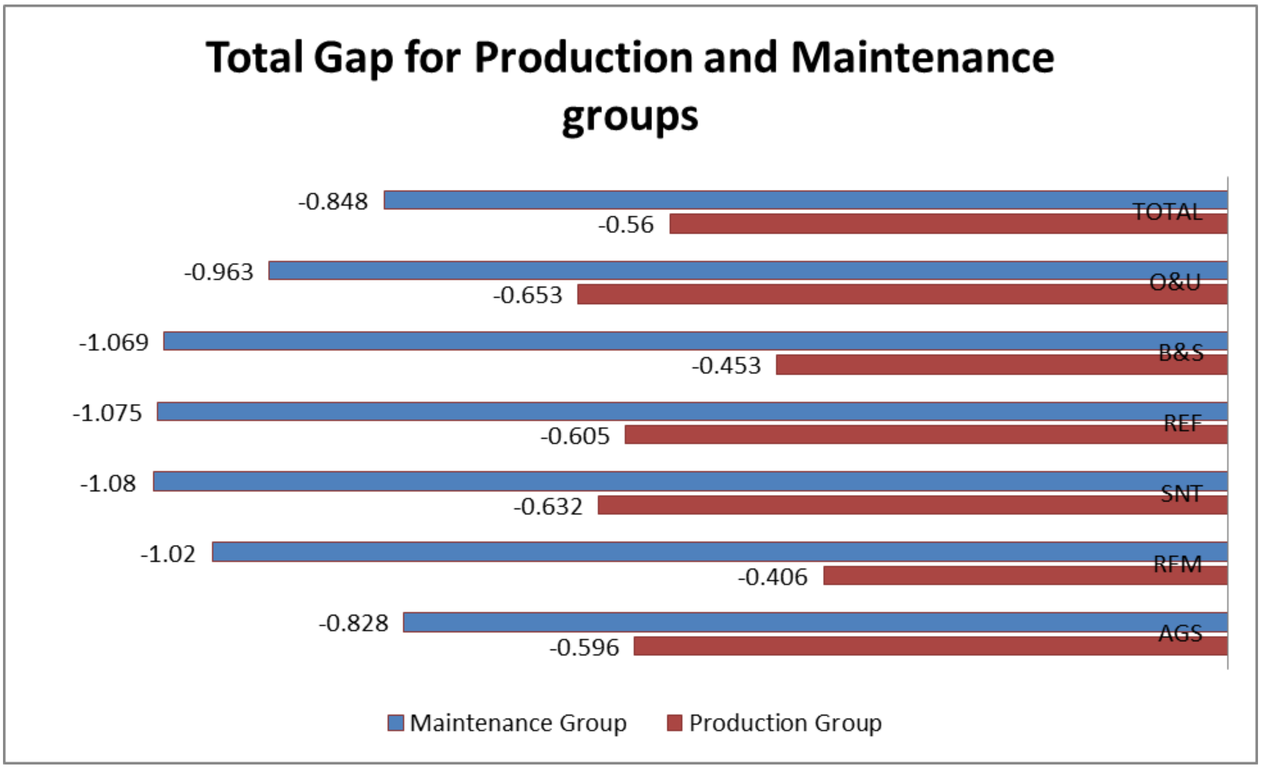

Figure 6.5 Total gap for the Production and Maintenance Groups

Figure 6.6 below indicates that on average, AGS represents the smallest PO&P gap of -0.341 on cost perspective while it represents the largest PO&P gap on production perspective of -1.154.

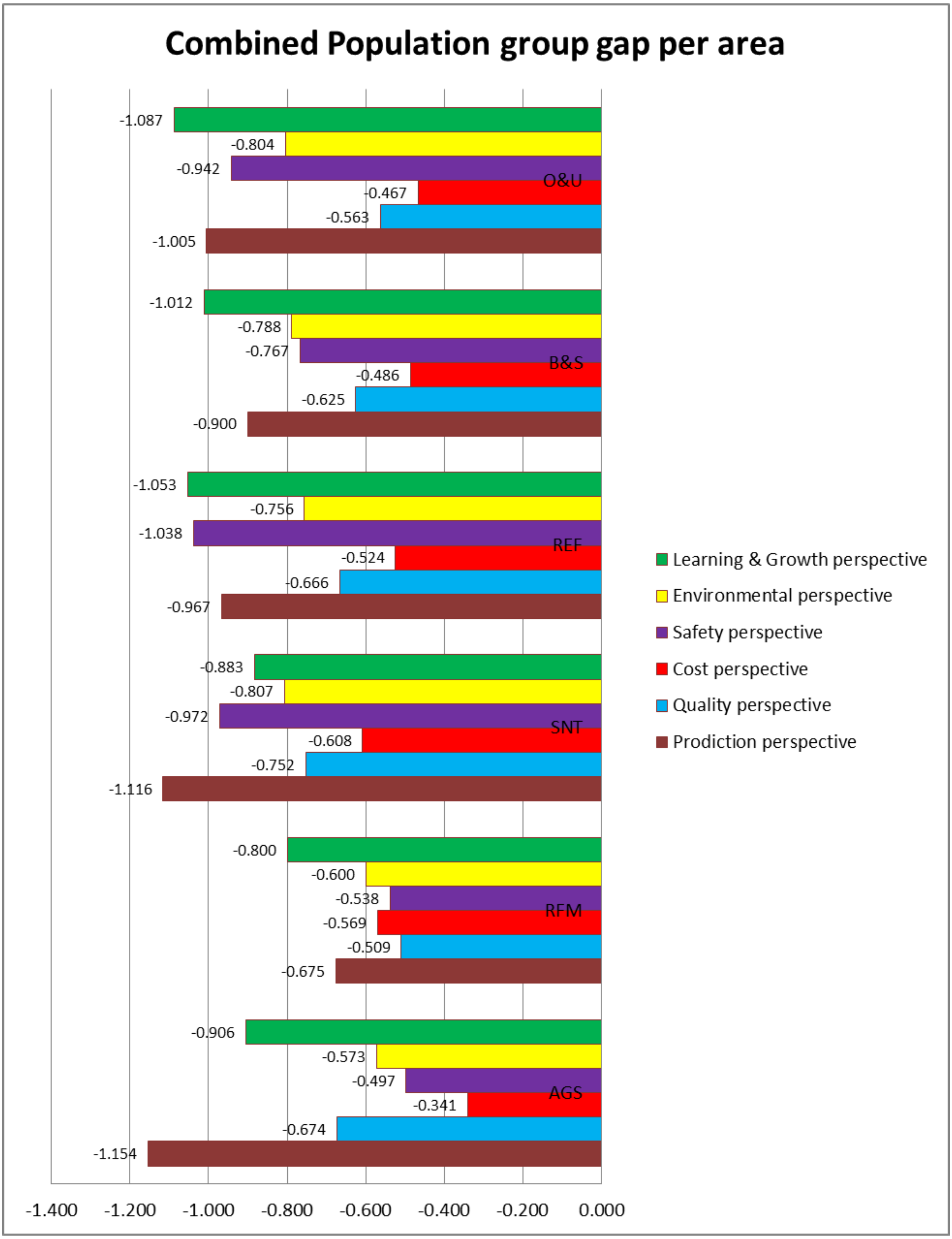

Figure 6.6 Combined population groups gap per area

Figure 6.7 represents an overall gap analysis for all six areas at the PetroSA GTL Refinery. It is evident that RFM represents the smallest PO&P gap of -0.615 while SNT represents the largest PO&P gap of -0.856

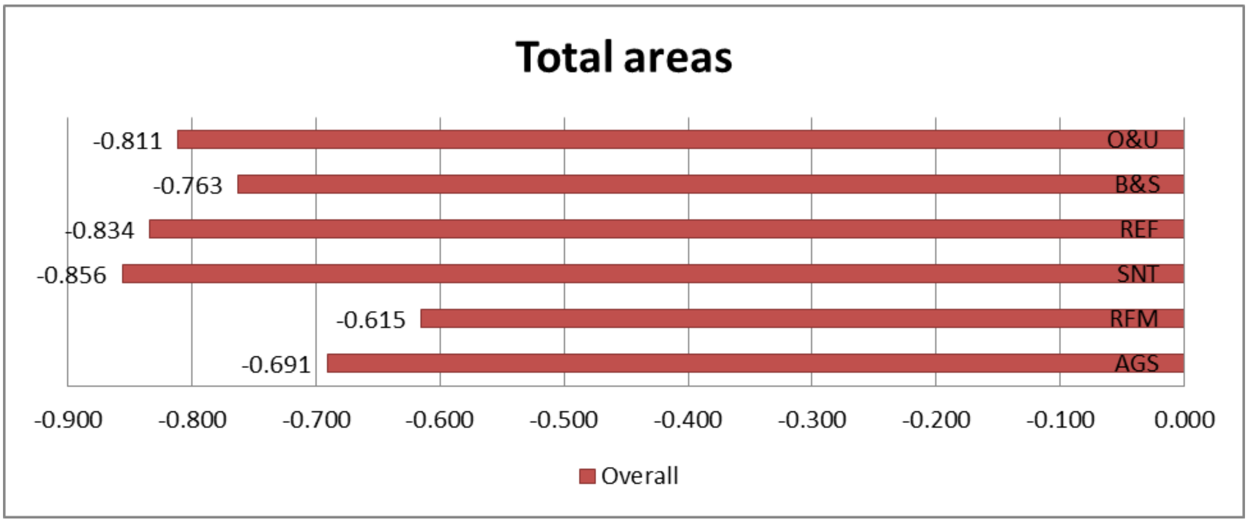

Figure 6.7 Combined areas gap analysis

6.4 THE MANAGEMENT SCORECARD (MS) GAP ANALYSIS

The PO&P gap is calculated by subtracting the PO&P expectations from the perceptions of the respondents (Gap = Perception – Expectations). As indicated in Chapter 1, section 1.10.2.6, the MS assessment tool comprises six dimensions, namely production perspective, quality perspective, cost perspective, safety perspective, environmental perspective and learning and growth perspective. The Maintenance and Production population groups completed the questionnaire in one section measuring the perception and the other section measuring the expectation. There were 32 questions for the Maintenance population Group and 35 questions for the Production population Group. For each question, the respondents rated on a Likert scale from 1 (strongly disagree) to 5 (strongly agree) whether they agreed with each statement. The MS score was then calculated as the difference between the perception and expectation scores of PO&P. This is referred to as the PO&P gap.

The following sections display calculated PO&P gaps for all six areas at the PetroSA GTL Refinery. The final gap value was calculated by taking the average score across the 32 and 35 questions respectively.

6.4.1 Gap analysis: AGS

Figures 6.8 to 6.21 below represent the MS gap analysis for the six dimensions of the PO&P for AGS. Appendices F and P display the PO&P gap for all six dimensions (perspectives) for AGS.

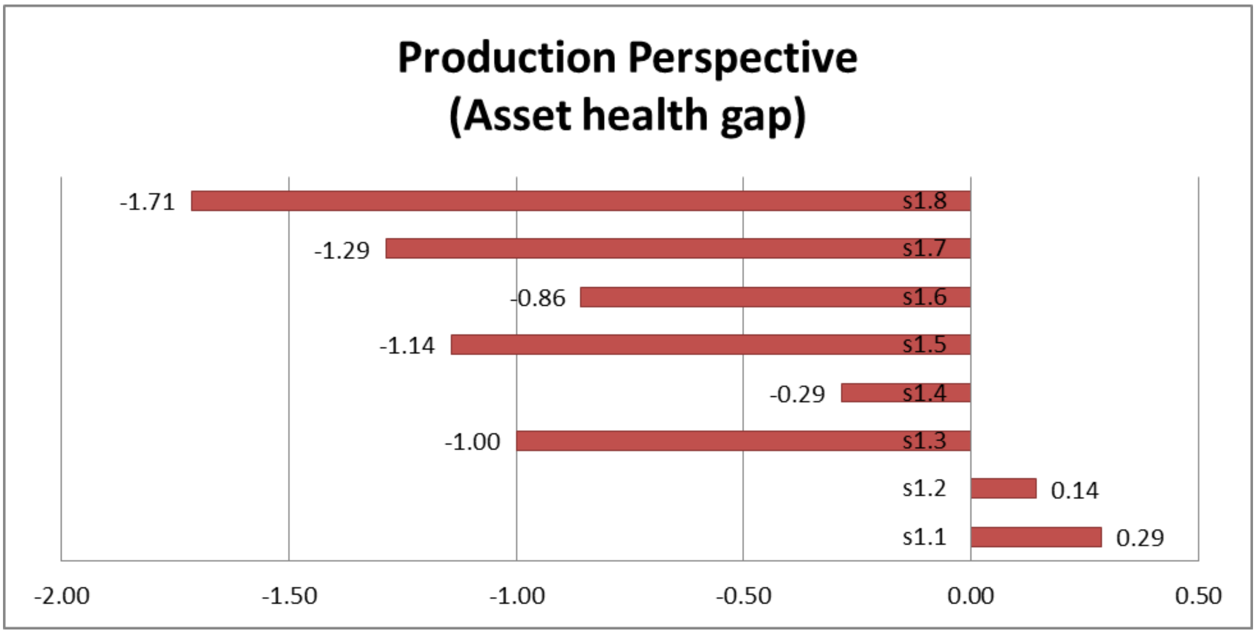

Figure 6.8 Gap analysis of production perspective for the Production Group

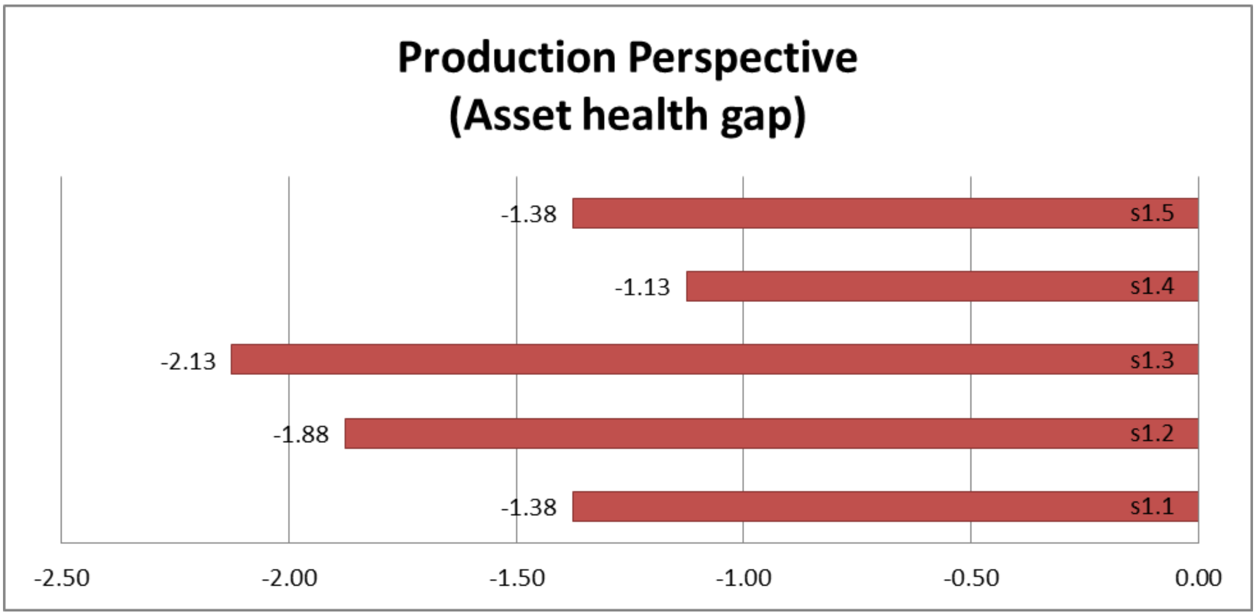

Figure 6.9 Gap analysis of production perspective for the Maintenance Group

Figures 6.8 and 6.9 indicate that AGS was perceived to be very low on compiling, approving and communicating the production plans and schedules to all relevant stakeholders. Adding to this, It is perceived that plant and equipment breakdowns have a negative impact on production volumes, hence daily, weekly and monthly PO was not within the scheduled or planned targets, plant and equipment were not operated according to design capacity and plant and equipment were not available, reliable, operable and efficient after the execution of maintenance activities. The organisational structure and size was perceived not to be supporting decisions to be made and implemented at the lower levels. It is further perceived that cross training of technical staff was ineffective and communication channels were delaying decisions and the flow of information.

Figures 6.10 and 6.11 below indicate that AGS was perceived to be negative, in that quality of the manufactured products was not within production specifications. This is supported by the perception that plant and equipment also contributed to the poor quality of products due to breakdowns, poor reliability, availability, operability that were not efficient after maintenance work was executed. Further indications are that the use of the Computerised Maintenance Management System (CMMS) was perceived to be negative due to incomplete and unreliable maintenance-related information.

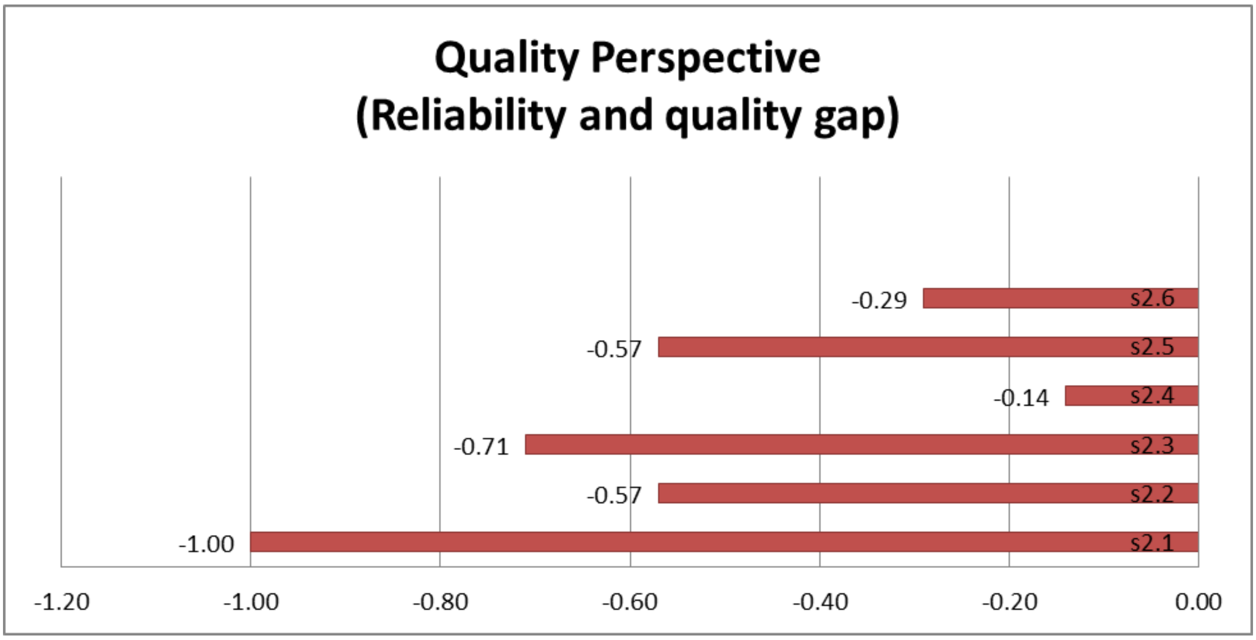

Figure 6.10 Gap analysis of quality perspective for the Production Group

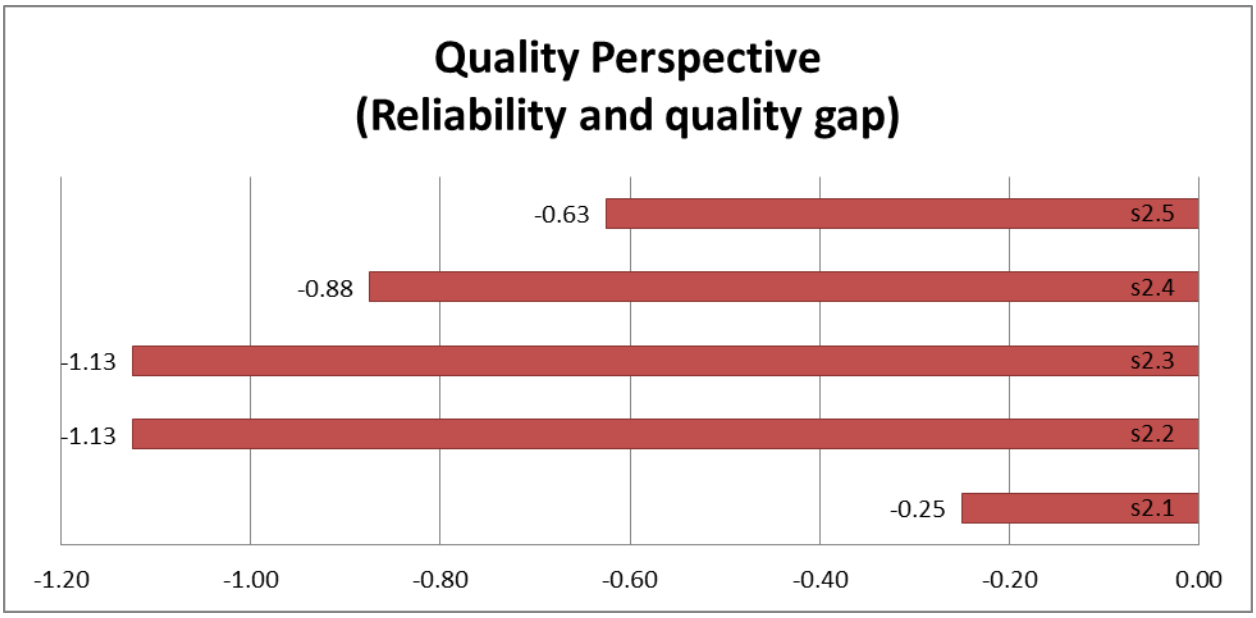

Figure 6.11 Gap analysis of quality perspective for the Maintenance Group

Figures 6.12 and 6.13 below indicate that AGS was perceived to be losing income and revenue because of low production volumes. This is supported by the perception that weekly, monthly and yearly revenue and income is not within the set target. Further indications are evident in terms of work planning that the AGS policy for planning maintenance work was perceived to be ineffective and the weekly, monthly and yearly look-ahead plans and schedules were non-existent. Supervisors were not supporting the planning concept. However, this is not supported by the perception that product prices and delivery of products to customers was not affected by plant and equipment breakdowns.

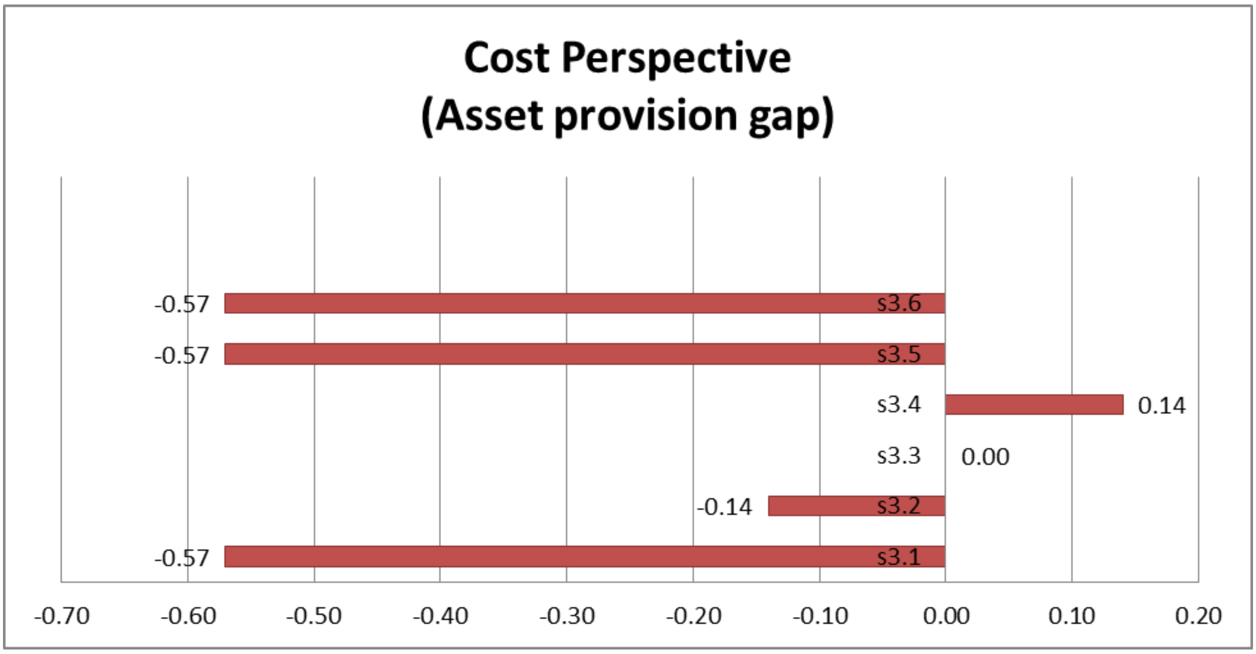

Figure 6.12 Gap analysis of cost perspective for the Production Group

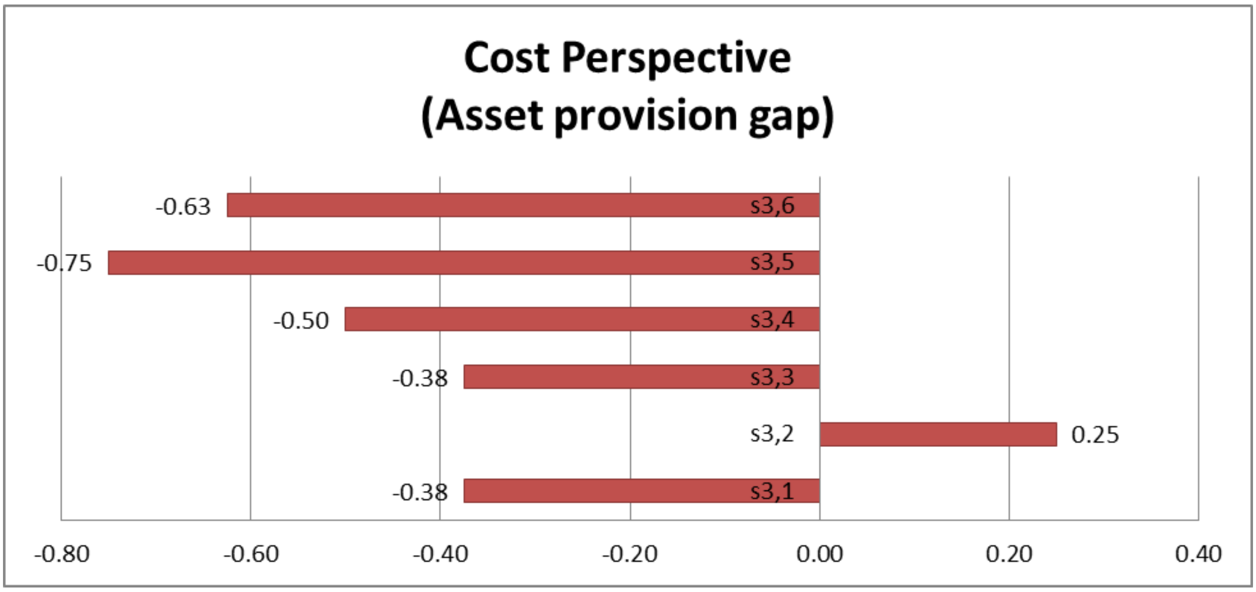

Figure 6.13 Gap analysis of cost perspective for the Maintenance Group

Figures 6.14 and 6.15 below indicate that AGS was perceived to have high lost-time injuries. This was supported by the perception that AGS compliance with regulatory requirements in terms of overdue Risk Based Inspections (RBIs) on vessels, pipelines and pressure safety valves was very low. AGS work measurement was perceived to be negative in that Key Performance Indicators (KPIs) were not complied with and communicated, the visual planning system was not effective and capacity planning was non-existent.

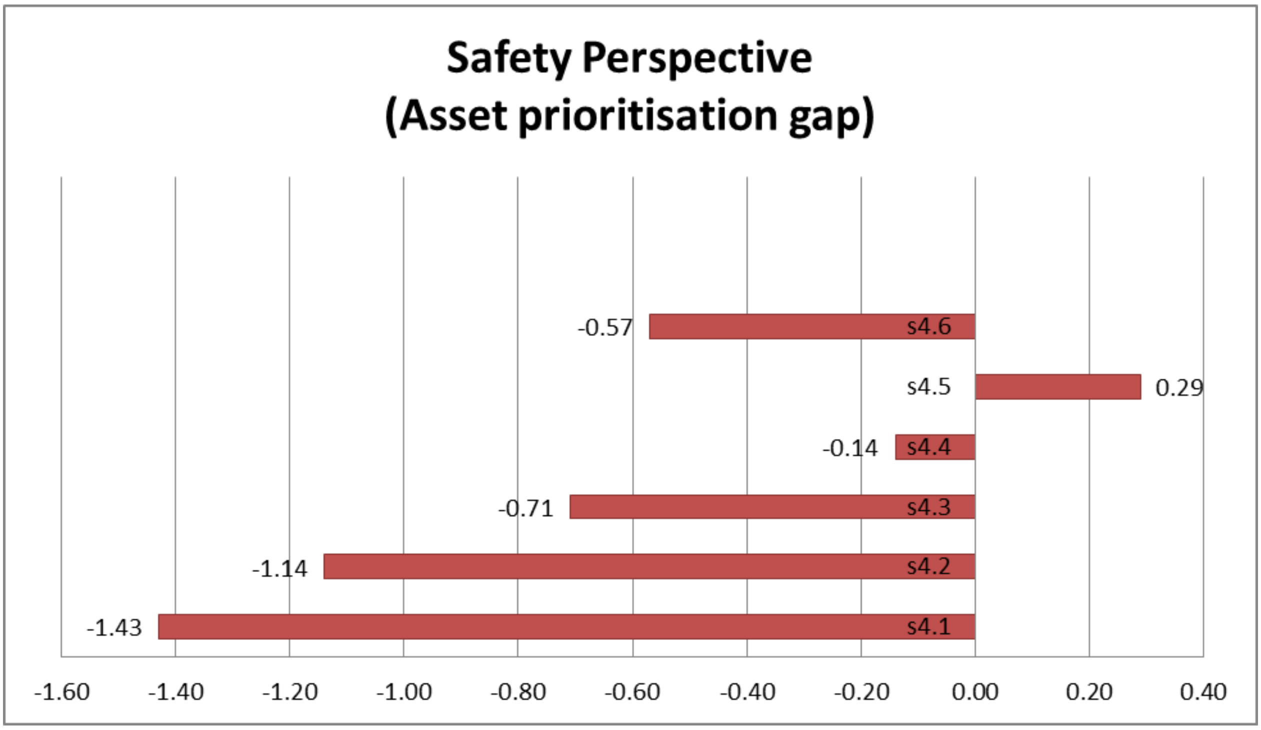

Figure 6.14 Gap analysis of safety perspective for the Production Group

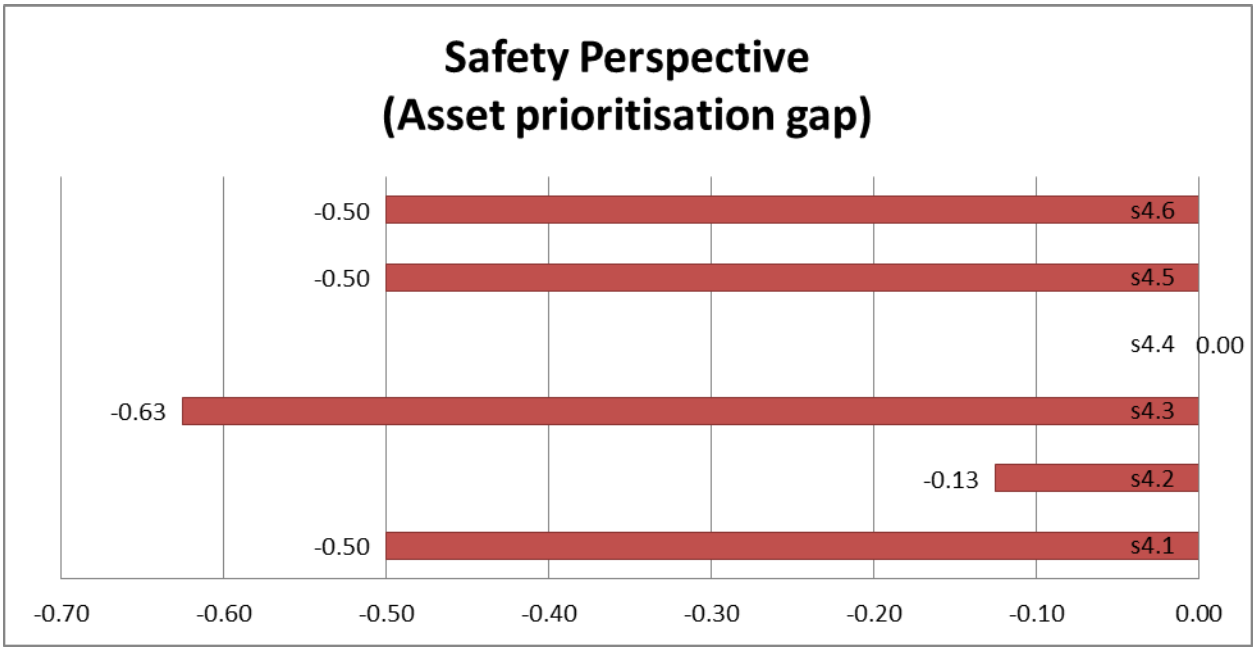

Figure 6.15 Gap analysis of safety perspective for the Maintenance Group

Figures 6.16 and 6.17 below indicate that AGS was perceived to be negative in terms of environmental perspective in that product spillages and priority 1 incidents were perceived to be very high. It is further perceived that stock levels are not defined and a part numbering system was not utilised.

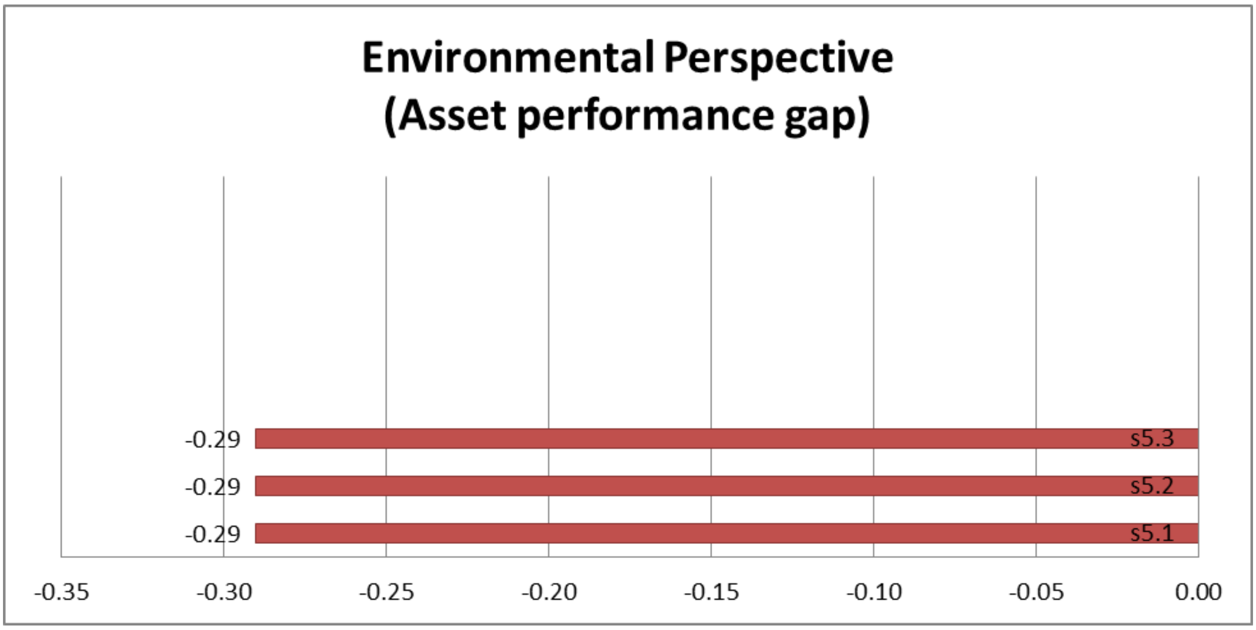

Figure 6.16 Gap analysis of environmental perspective for the Production Group

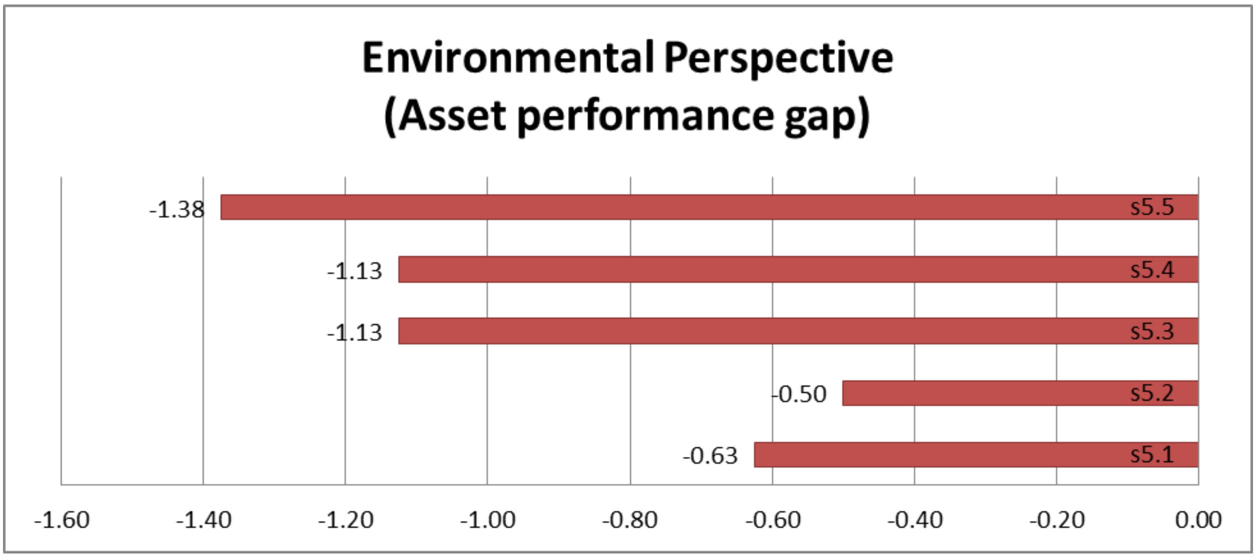

Figure 6.17 Gap analysis of environmental perspective for the Maintenance Group

Figures 6.18 and 6.19 below indicate that AGS was perceived to be negative in terms of learning and growth, in that cross training of technical staff, supervisors and inspectors was low. Further perceptions are that the work prioritisation system was not effective and scheduled jobs were not completed on time.

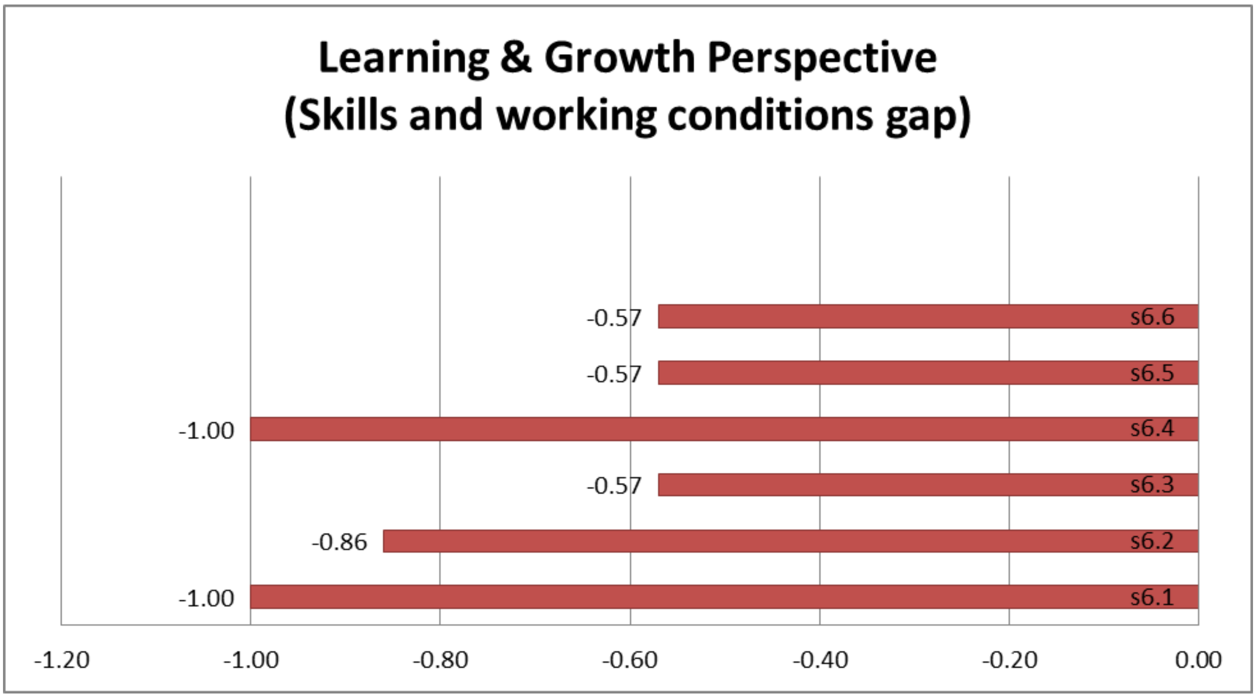

Figure 6.18 Gap analysis of learning and growth for the Production Group

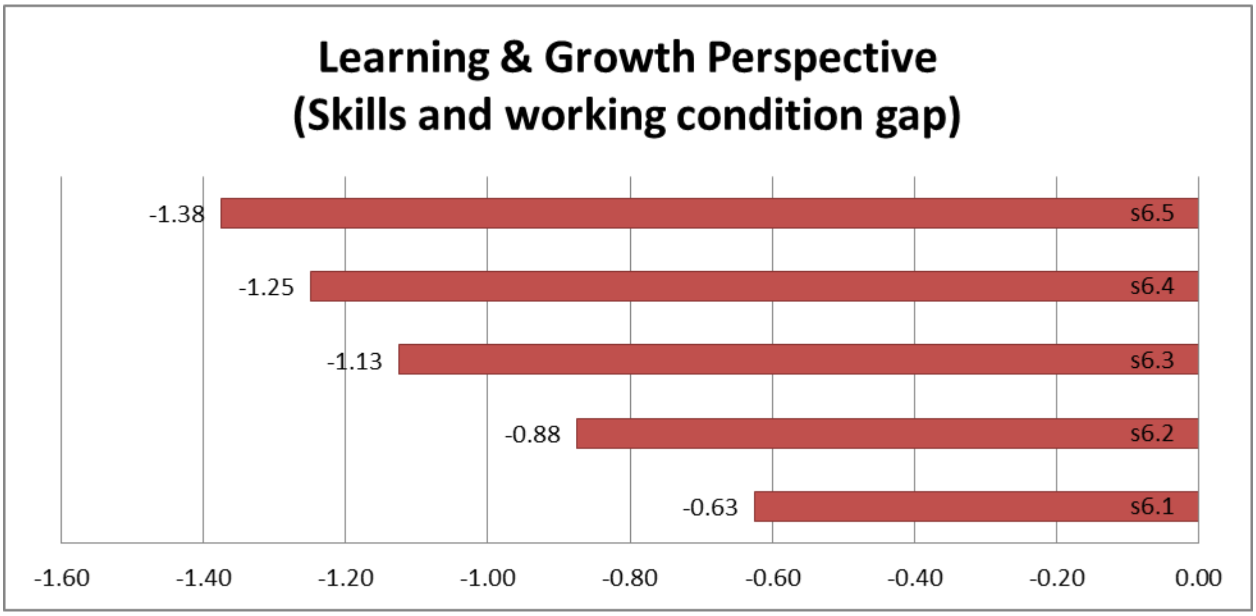

Figure 6.19 Gap analysis of learning and growth perspective for the Maintenance Group

According to the data displayed in Figures 6.20 and 6.21 below and supported by the information contained in appendices E and P, it is evident that on average, expectations for reducing breakdowns on plant and equipment were very high. This is followed by the expectation of manufacturing products consistently and improving the skills, competencies and knowledge of maintenance and production personnel. The perception of planning and scheduling production volumes in accordance with plant and equipment capacity is high. On average the respondents expectations exceeded their perceptions.

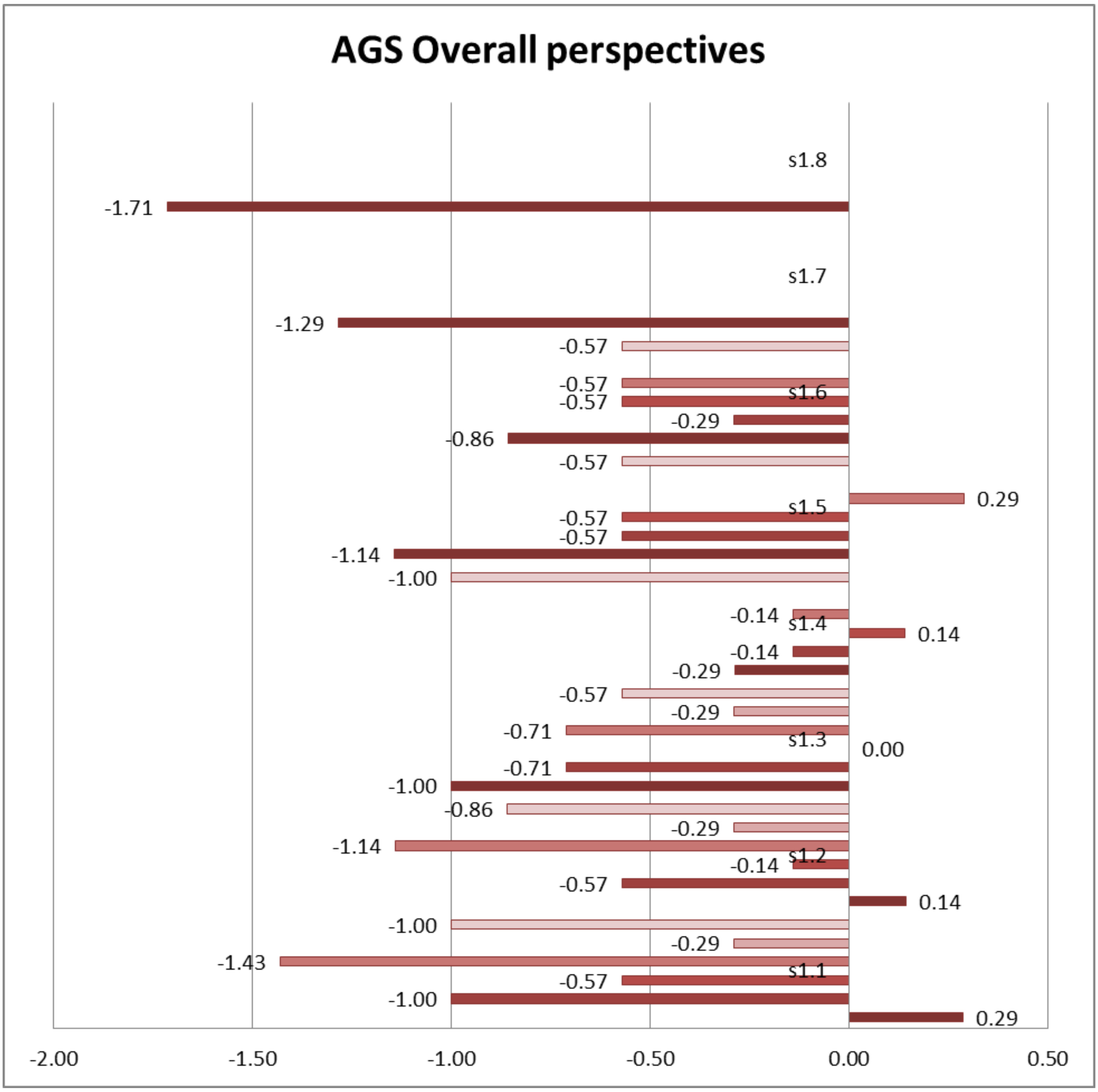

Figure 6.20 Overall dimensions gap analysis for the Production Group

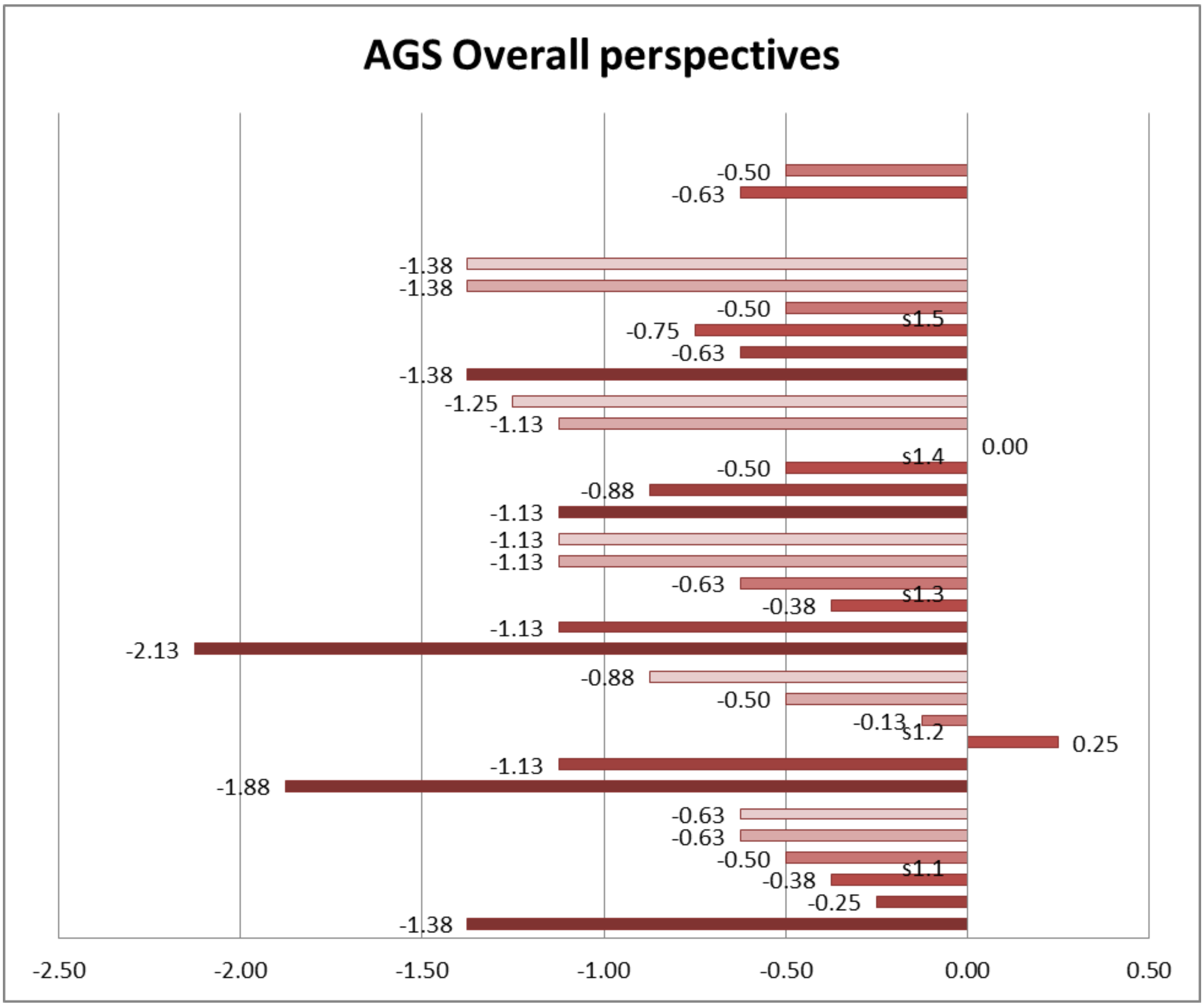

Figure 6.21 Overall dimensions gap analysis for the Maintenance Group

6.4.2 Gap analysis: Reforming (RFM)

Figures 6.22 and 6.33 below represent the MS gap analysis for the six dimensions of the PO&P for RFM. Appendices G and Q display the PO&P gap for all six dimensions (perspectives) for RFM.

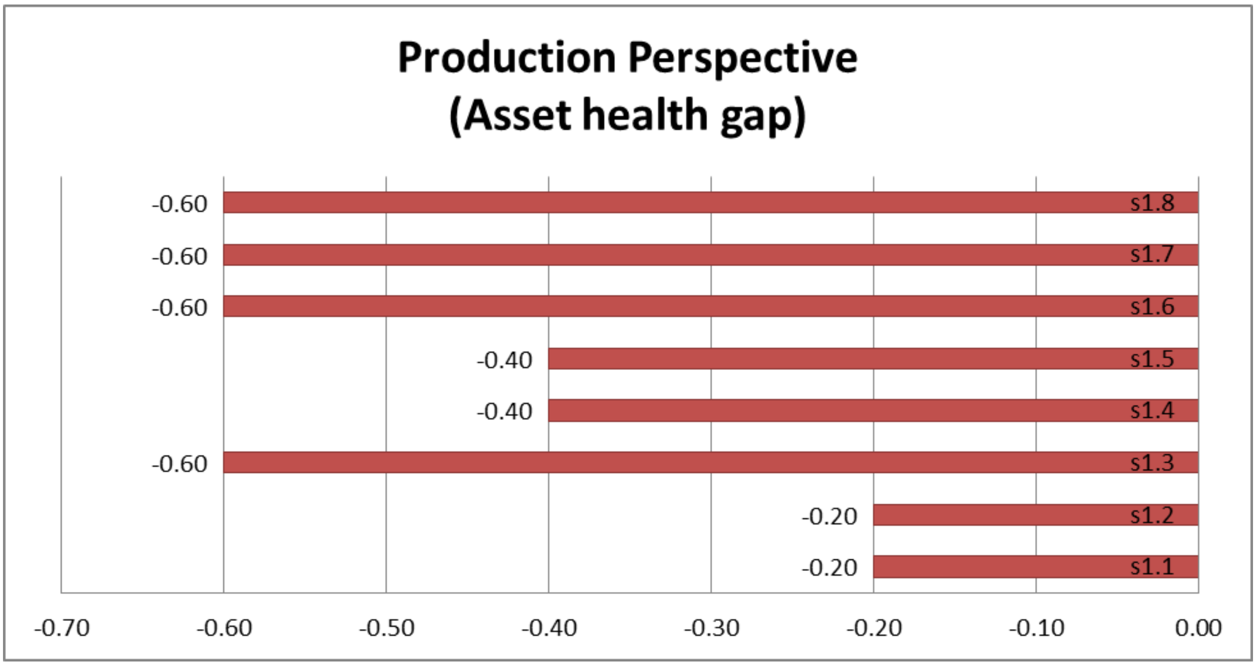

Figure 6.22 Gap analysis of production perspective for the Production Group

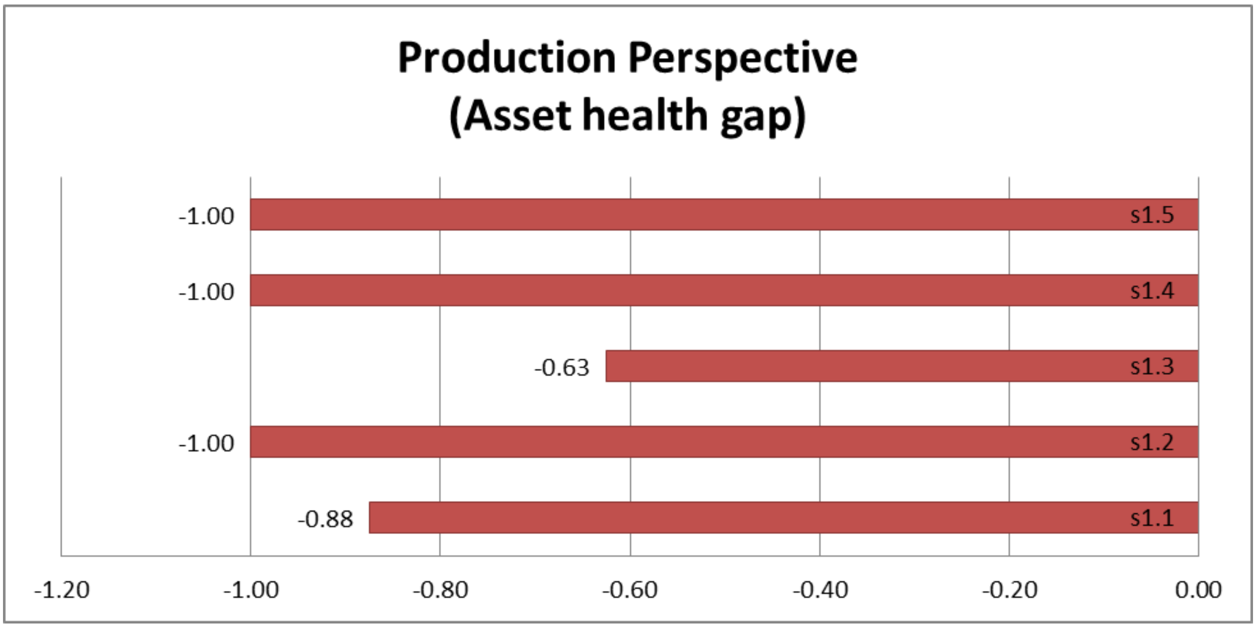

Figure 6.23 Gap analysis of production perspective for the Maintenance Group

Figures 6.22 and 6.23 above indicate that RFM was perceived to be negative in that compilation, approval and communication of production plans and schedules to all relevant stakeholders was very low. It is perceived that plant and equipment breakdowns have a positive impact on production volumes hence daily, weekly and monthly PO was not within the scheduled or planned targets, plant and equipment were not operated according to design capacity and plant and equipment were not available, reliable, operable and efficient after the execution of maintenance activities. The organisational structure and size is perceived to be negative in that decisions are confined to executive management, cross training of technical staff is ineffective and communication channels are hindered by “red tape”, thus delaying decisions and the flow of information.

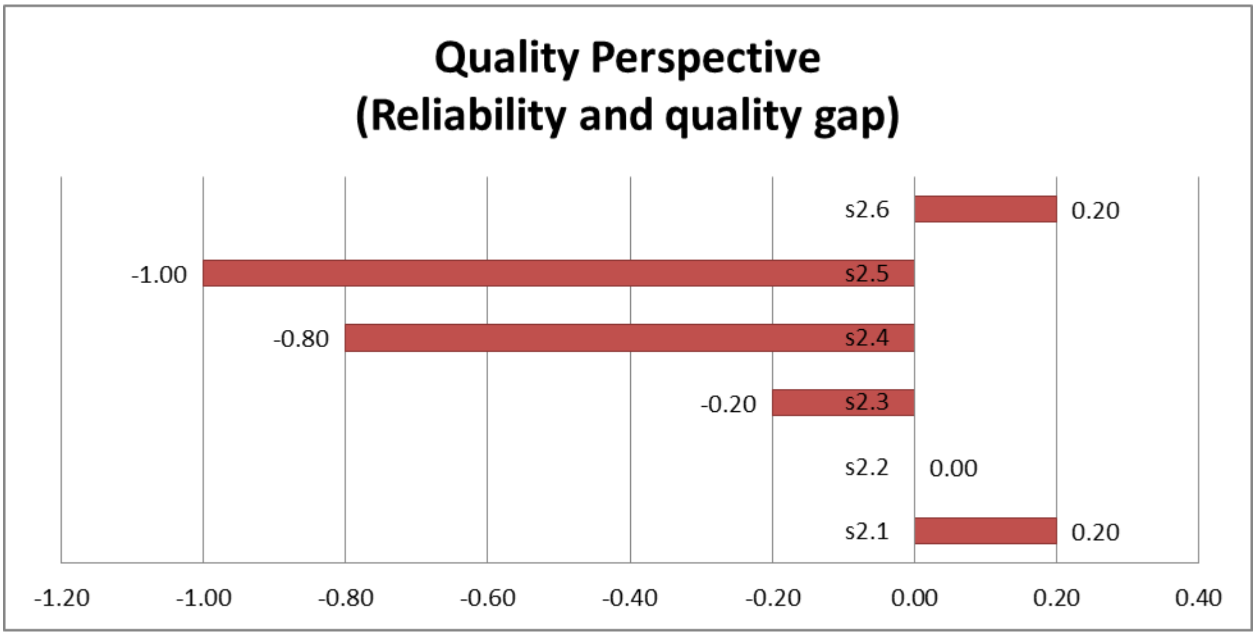

Figure 6.24 Gap analysis of quality perspective for the Production Group

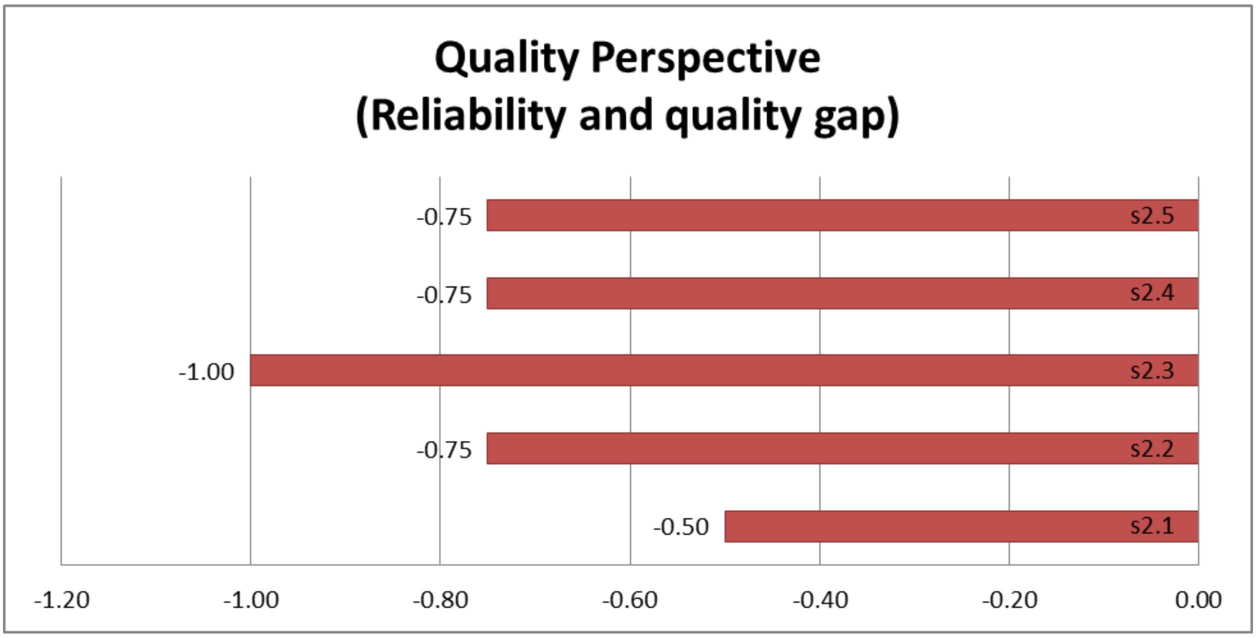

Figure 6.25 Gap analysis of quality perspective for the Maintenance Group

Figures 6.24 and 6.25 above indicate that the quality of RFM products was perceived to be below required specifications. This is supported by the perception that plant and equipment contribute to poor quality of products because of breakdowns, poor reliability, availability, operability and that they were not efficient after maintenance work is executed. Further indications are that the use of CMMS was perceived to be negative as a result of incomplete and unreliable maintenance-related information

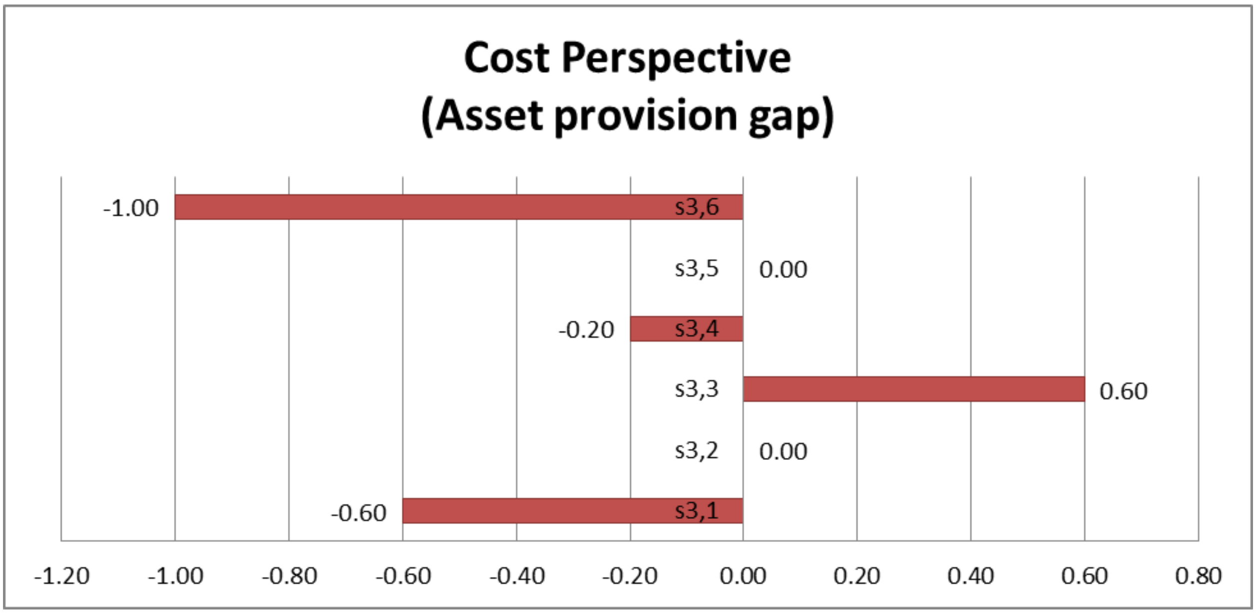

Figure 6.26 Gap analysis of cost perspective for the Production Group

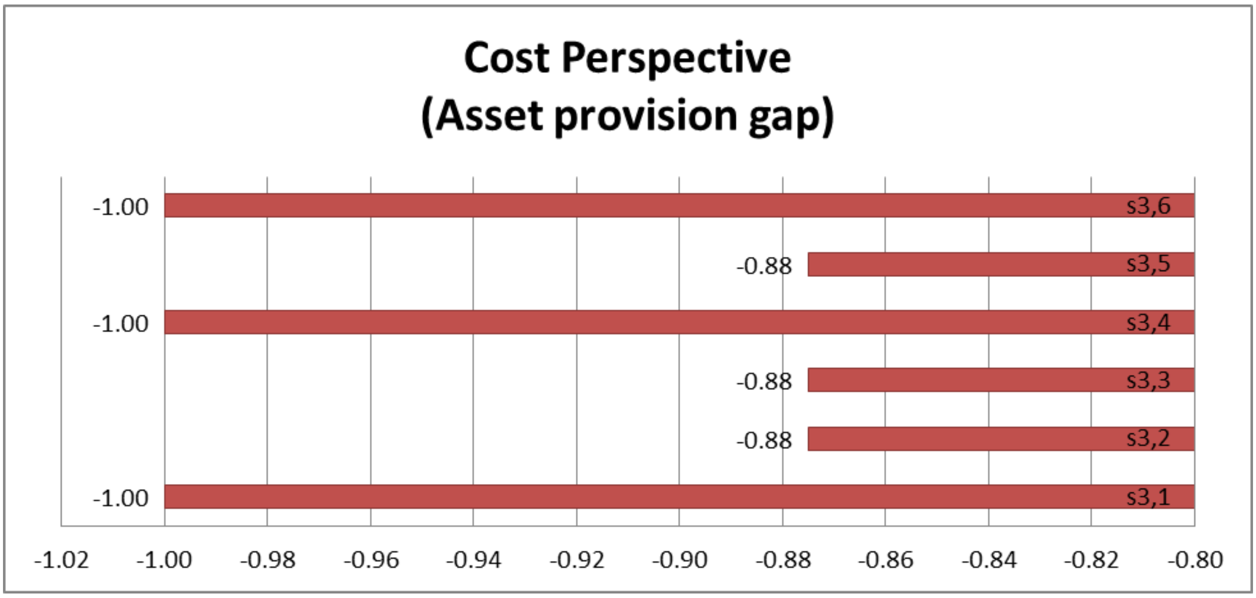

Figure 6.27 Gap analysis of cost perspective for the Maintenance Group

Figures 6.26 and 6.27 above indicate that RFM was perceived to be losing income and revenue due to low production volumes. This is supported by the perception that product prices and delivery of products to customers were impacted by plant and equipment breakdowns. It is further supported by the perception that weekly, monthly and yearly revenue and income was not within the set target. However, this is not supported by the perception that product prices were not reduced due to poor quality and production reworks.

Figure 6.28 Gap analysis of safety perspective for the Production Group

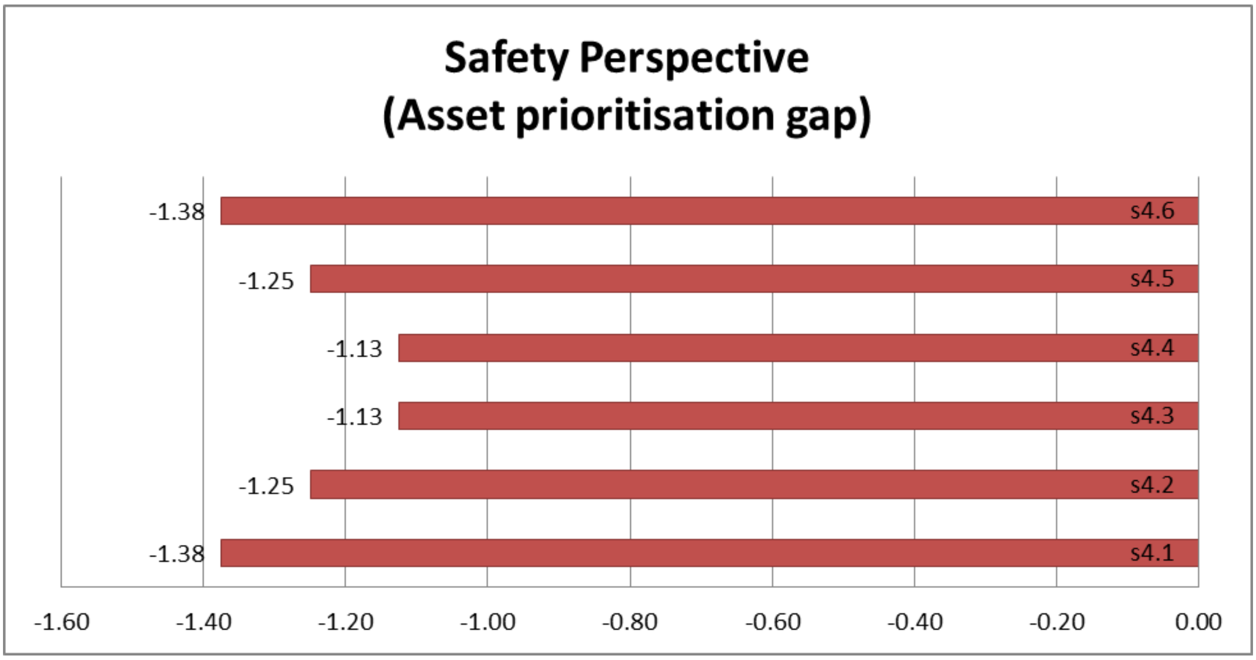

Figure 6.29 Gap analysis of safety perspective for the Maintenance Group

Figures 6.28 and 6.29 above indicate that RFM was perceived to be negative in that it did not comply with regulatory requirements, especially overdue RBI vessels, pipelines and pressure safety valves. This was supported by the level of absenteeism and injuries, which were perceived to be low. It is perceived that the visual planning system, capacity planning system and performance management system were also perceived to be very low.

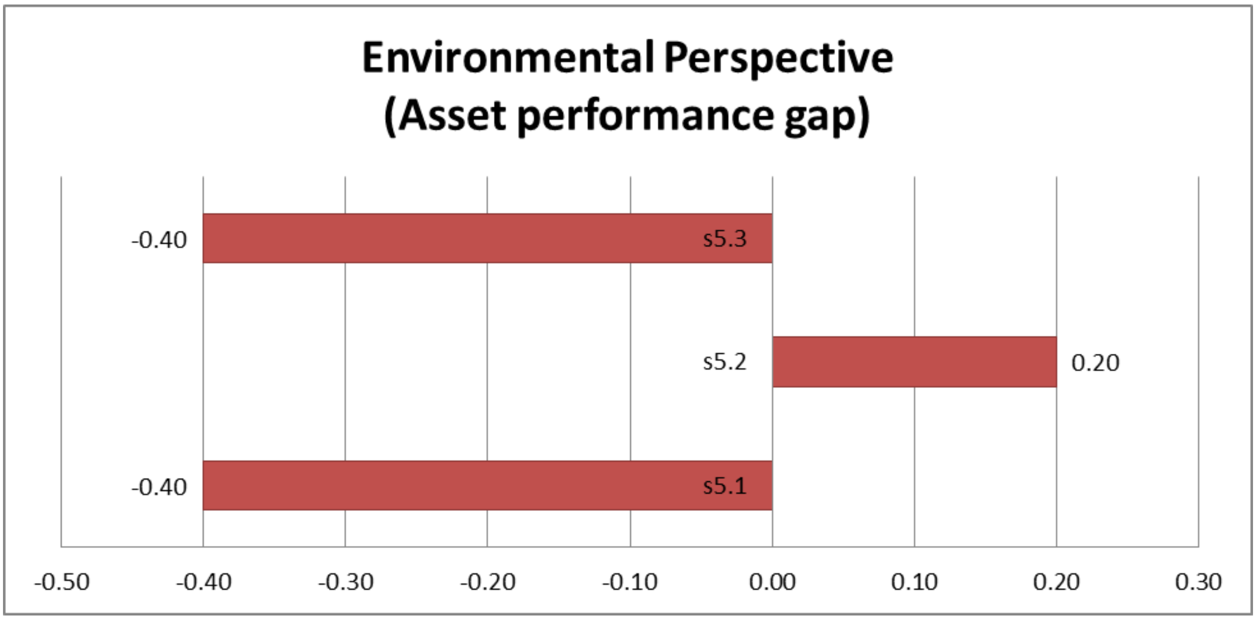

Figure 6.30 Gap analysis of environmental perspective for the Production Group

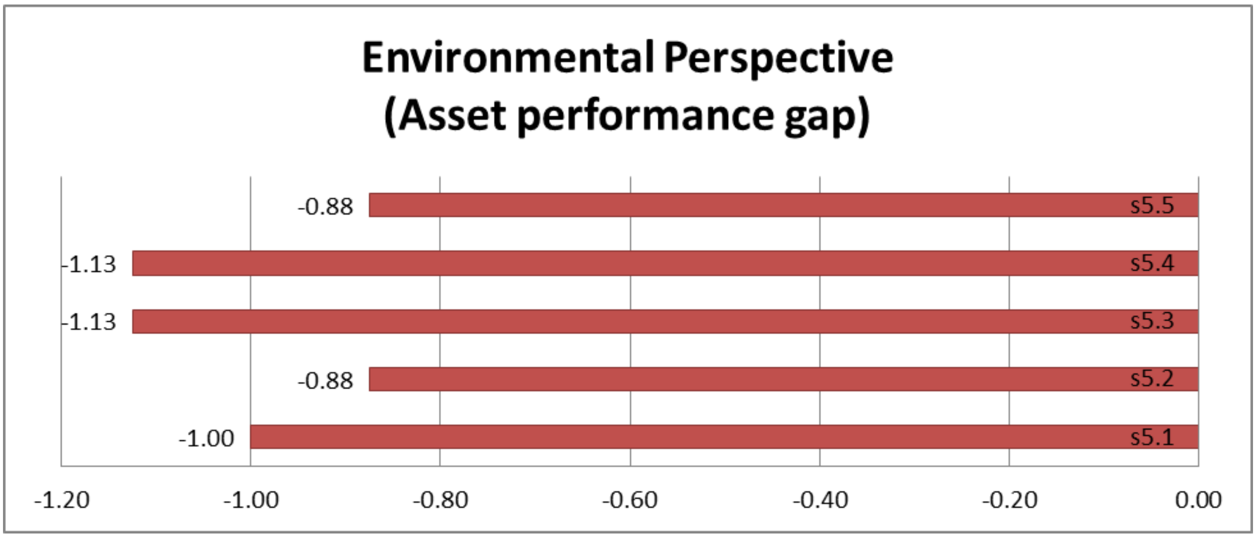

Figure 6.31 Gap analysis of environmental perspective for the Maintenance Group

Figures 6.30 and 6.31 above indicate that RFM was perceived to have very high minor injuries, product spillages and overdue priority 1 incidents. This is supported by the perception that material control, support, planning and availability were also low.

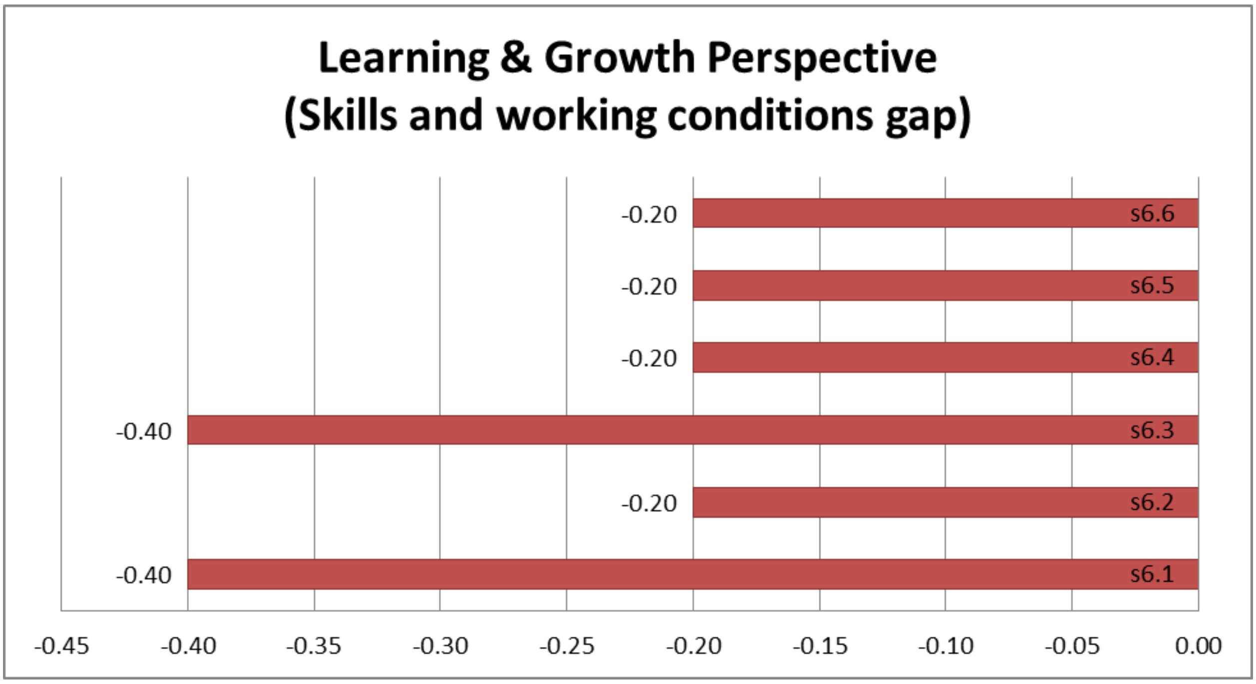

Figure 6.32 Gap analysis of learning and growth for the Production Group

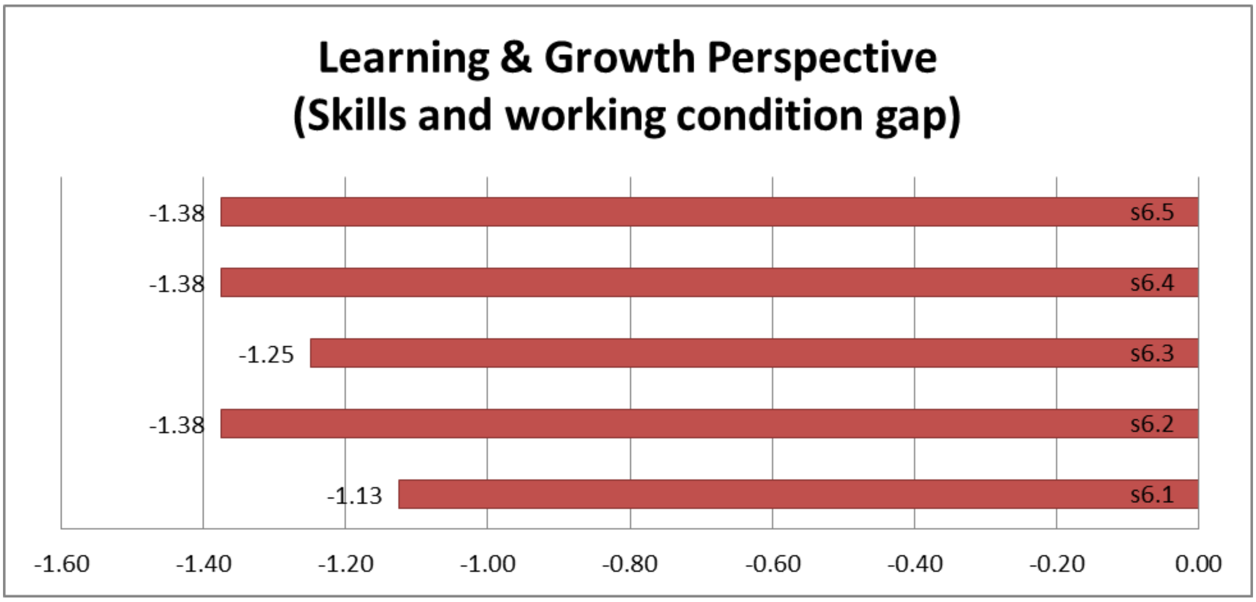

Figure 6.33 Gap analysis of learning and growth perspective for the Maintenance Group

Figures 6.32 and 6.33 above indicate that RFM was perceived to be negative or low on cross training of artisans, operators, supervisors, technicians, engineers and inspectors. Further perceptions are that the work prioritisation system was not effective, resource planning and allocation was low and scheduled jobs were not completed on time.

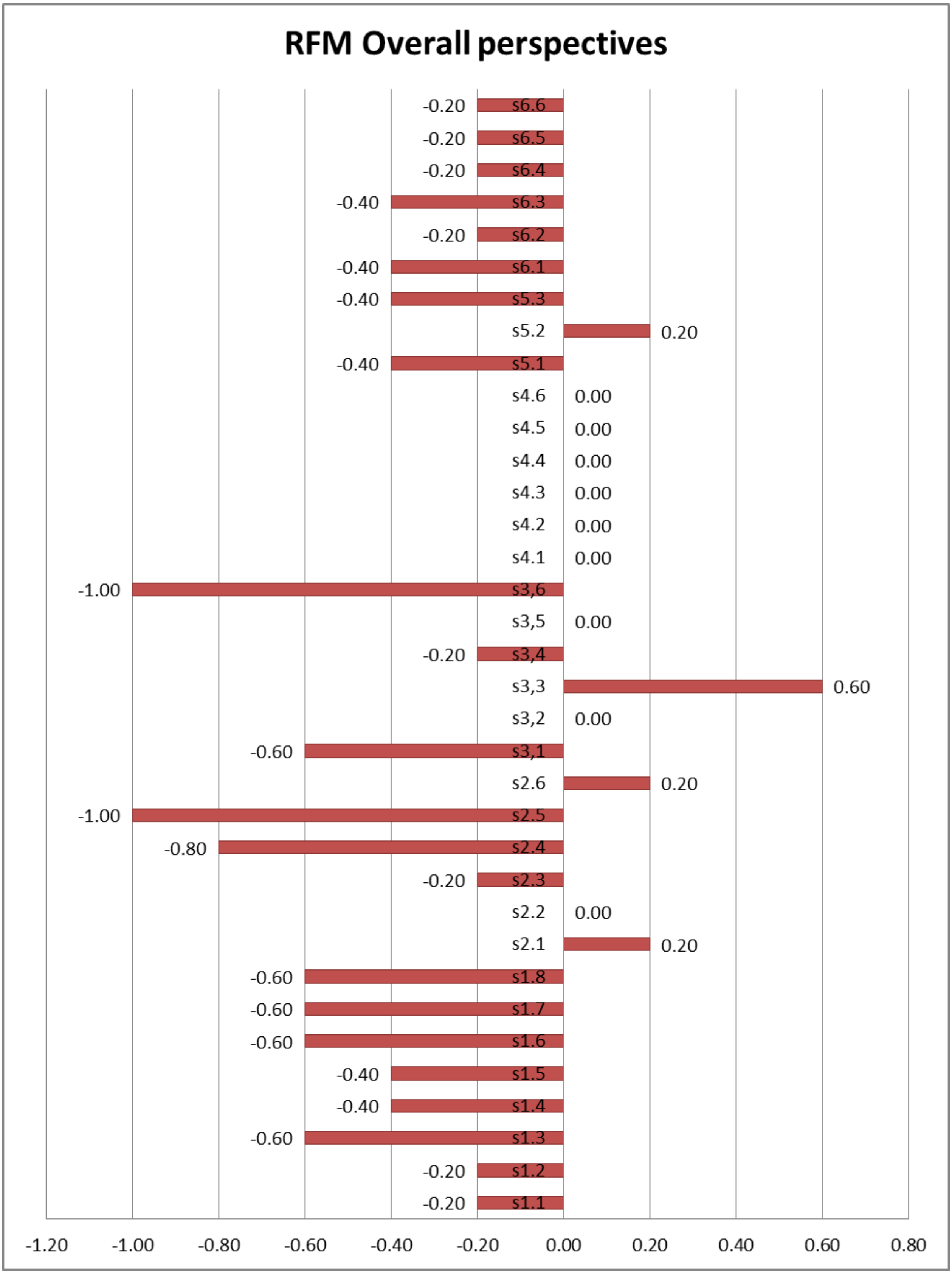

Figure 6.34 Overall dimensions gap analysis for the Production Group

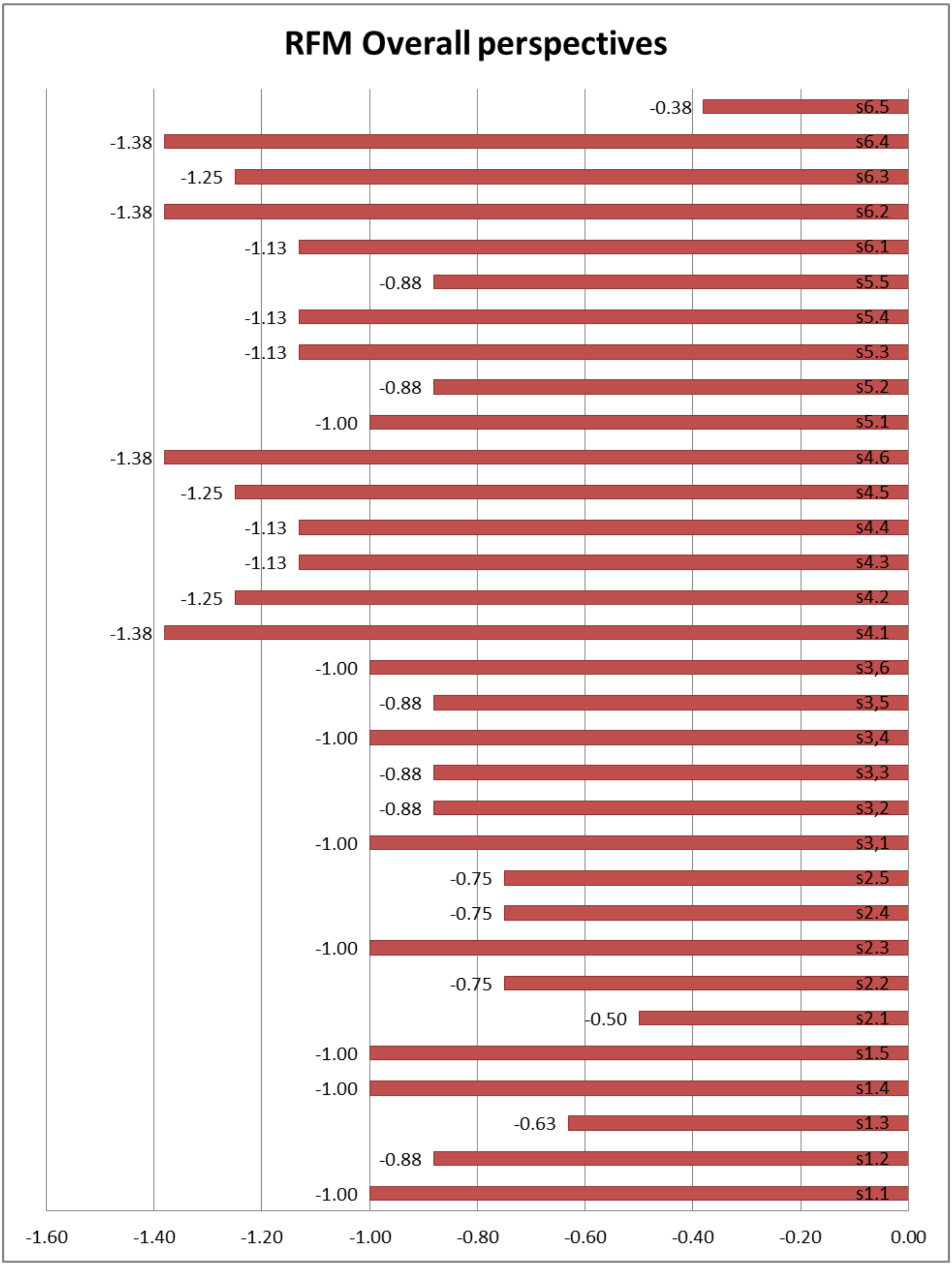

Figure 6.35 Overall dimensions gap analysis for the Maintenance Group

According to the data displayed in Figures 6.34 and 6.35 above, it is evident that, on average, expectations with regards to performance management, resource planning and allocation, completing work on time and cross training of personnel exceeded perceptions.

6.4.3 Gap analysis: Synthol (SNT)

Figures 6.36 and 6.49 below represent the MS gap analysis for the six dimensions of the PO&P for SNT. Appendices H and R display the PO&P gap for all six dimensions (perspectives) for SNT.

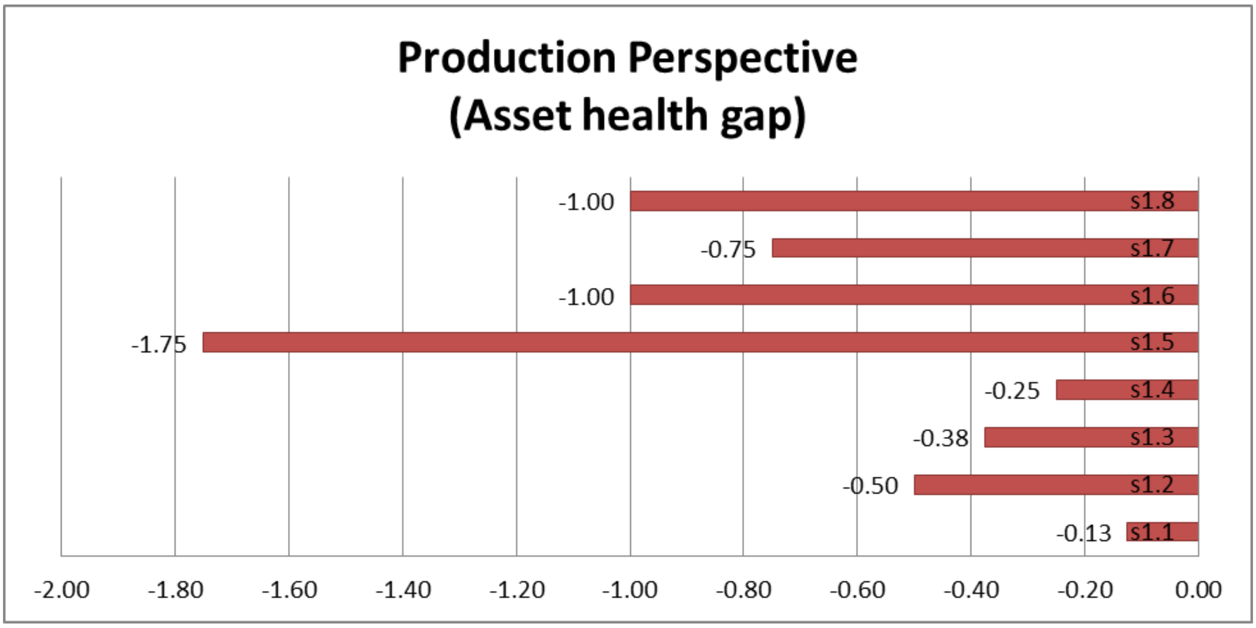

Figure 6.36 Gap analysis of production perspective for the Production Group

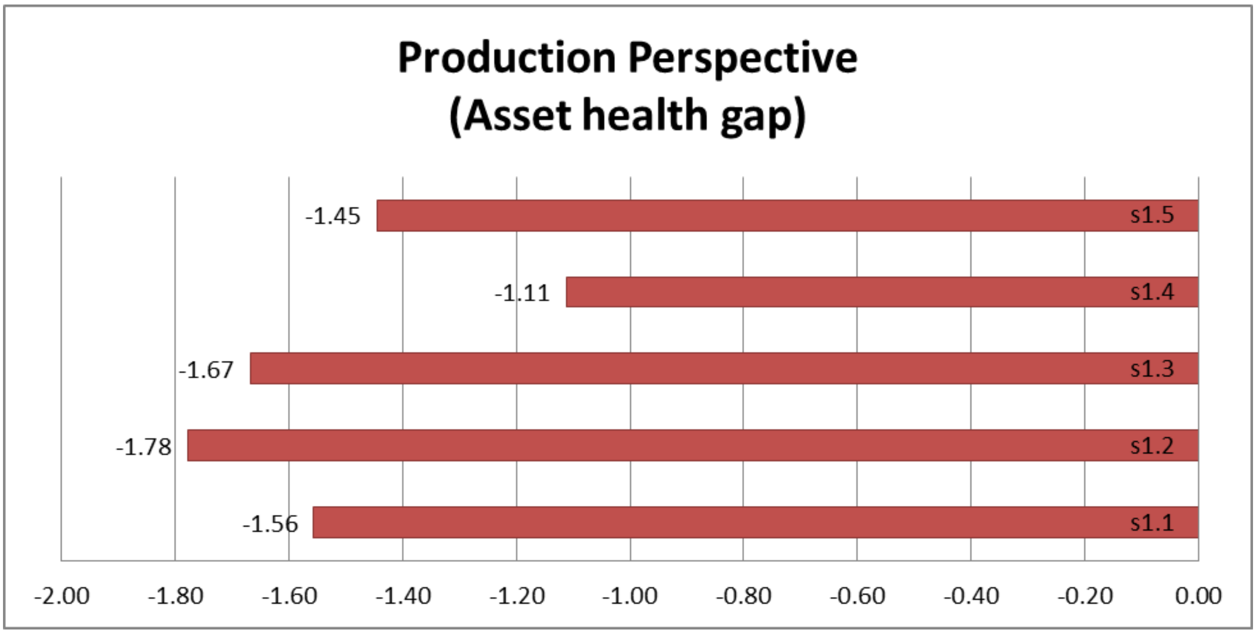

Figure 6.37 Gap analysis of production perspective for the Maintenance Group

Figures 6.36 and 6.37 above indicate that SNT was perceived to be negative in that compilation, approval and communication of production plans and schedules to all relevant stakeholders was very low. This is supported by the perception that production volumes were reduced due to plant and equipment breakdowns and that weekly and monthly PO was not within the scheduled or planned targets, plant and equipment were not operated per design capacity and plant and equipment was not available, reliable, operable and efficient after the execution of maintenance activities. The organisational structure and size was perceived to be negative in that decisions are confined to executive management, cross training of technical staff was ineffective or low and communication channels are hindered by “red tape”, thus delaying decisions and the flow of information.

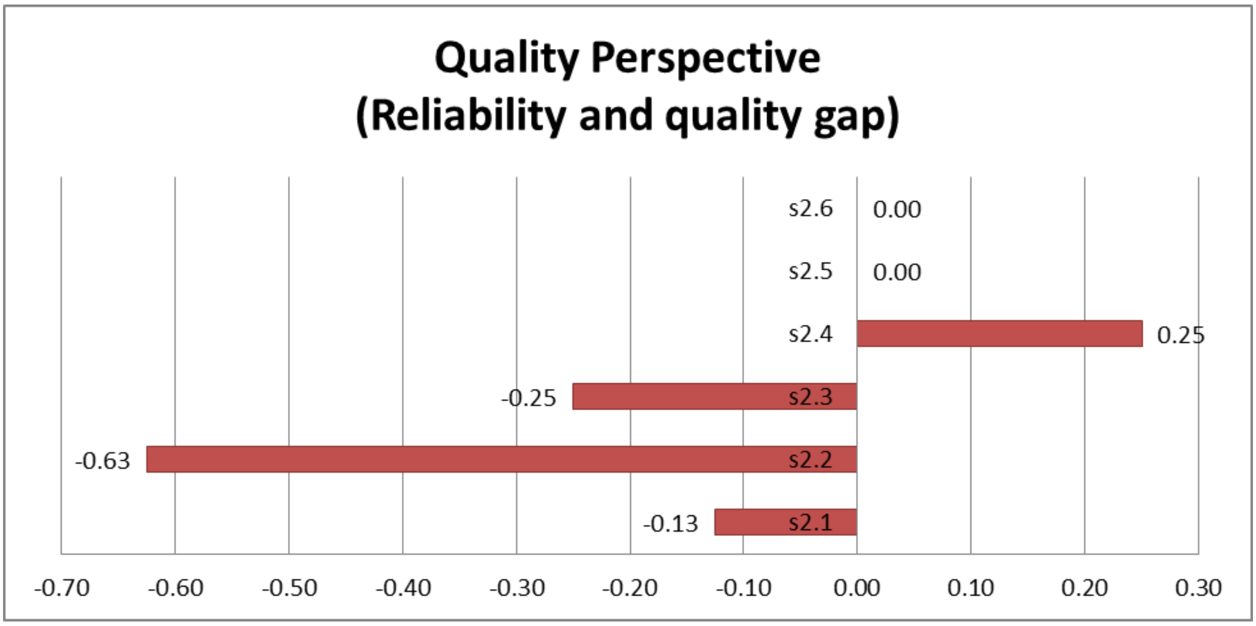

Figure 6.38 Gap analysis of quality perspective for the Production Group

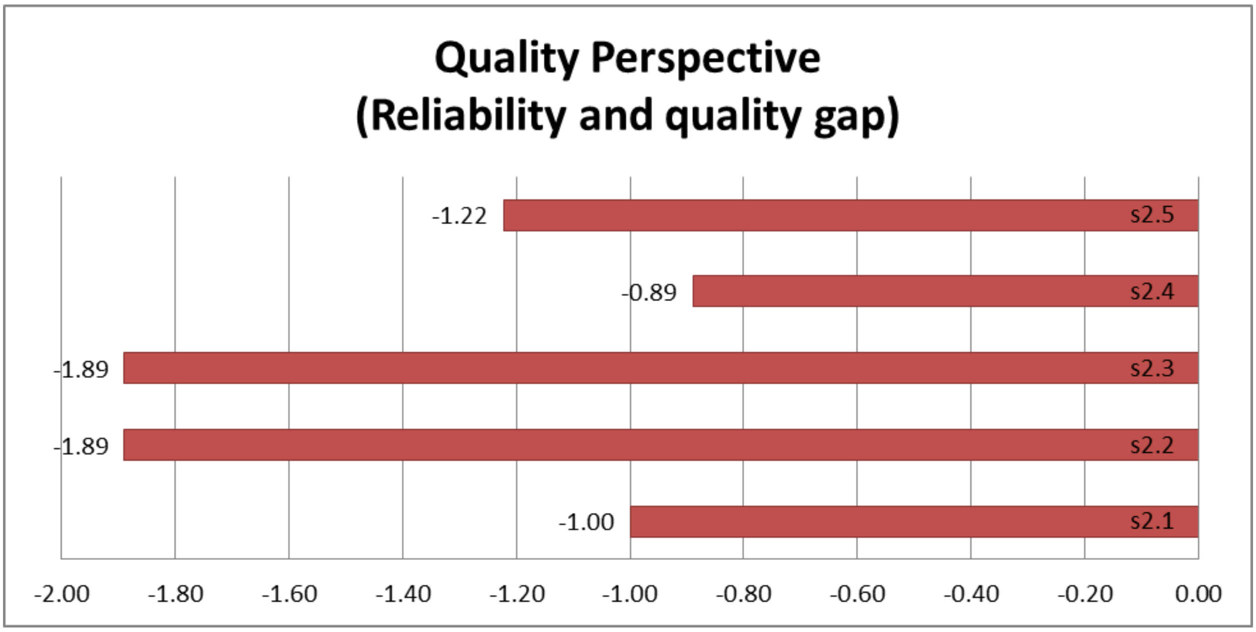

Figure 6.39 Gap analysis of quality perspective for the Maintenance Group

Figures 6.38 and 6.39 above indicate that SNT was perceived to be negative in that it was losing income and revenue due to low production volumes. This is supported by the perception that weekly, monthly and yearly production plans and schedules were not compiled, approved and communicated and planning of work was not done effectively. However, this is not supported by the perception that product prices were not reduced due to the quality of products and that the company was not losing income and revenue due to plant and equipment breakdowns.

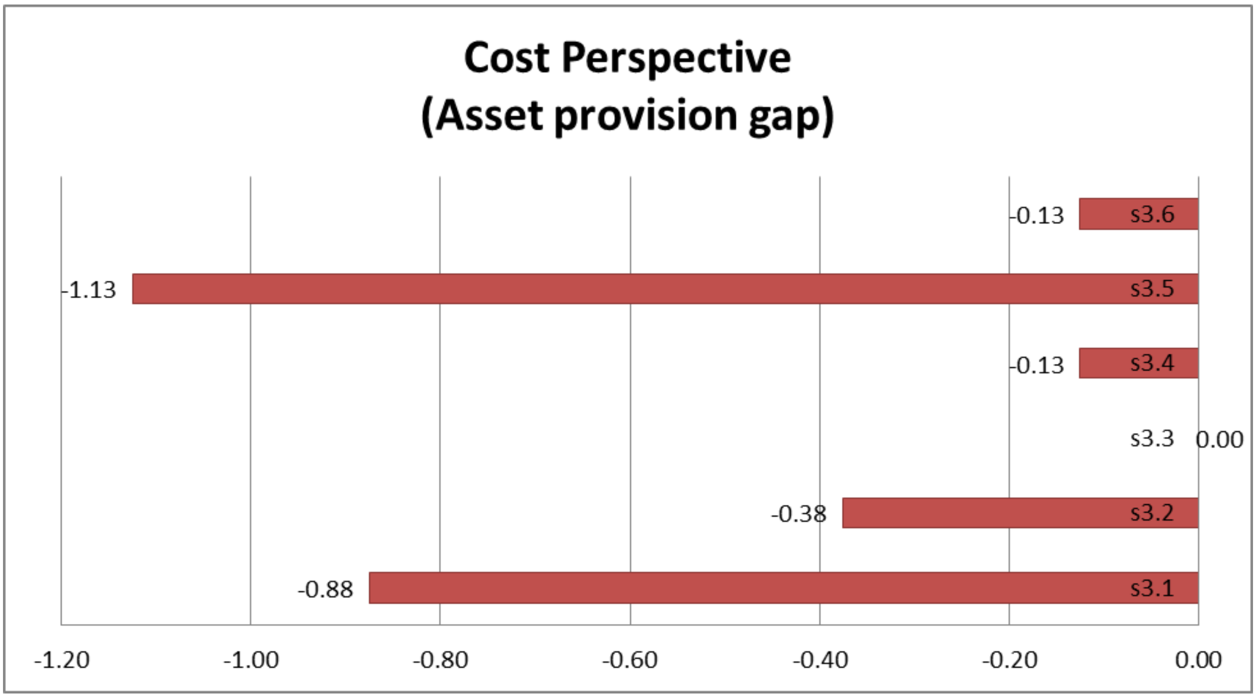

Figure 6.40 Gap analysis of cost perspective for the Production Group

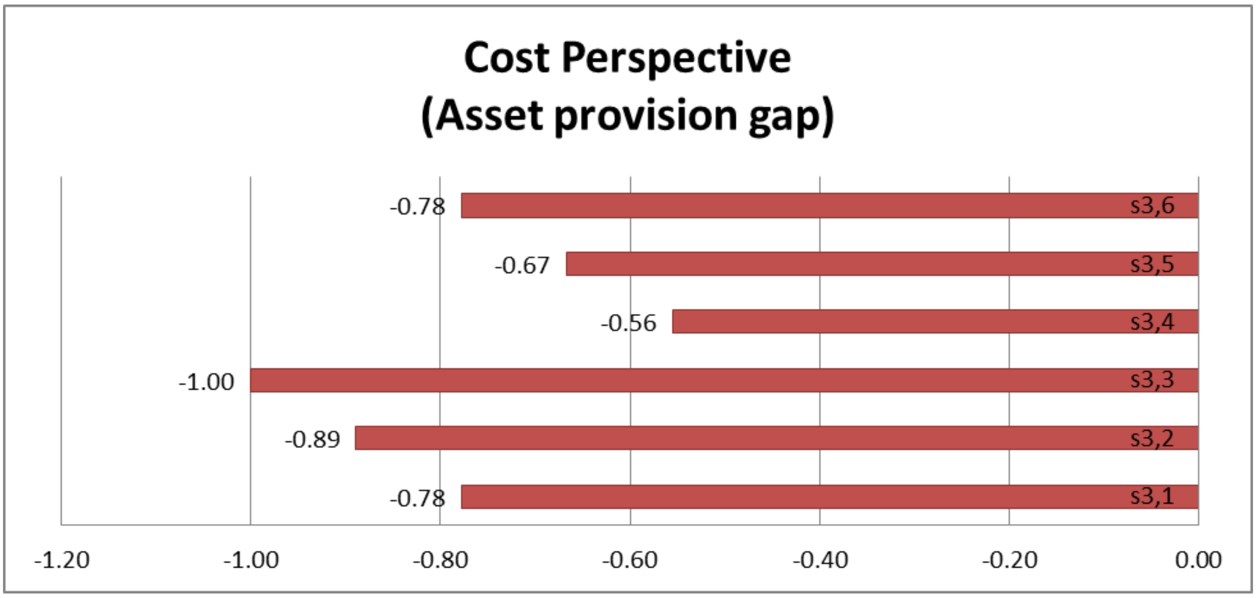

Figure 6.41 Gap analysis of cost perspective for the Maintenance Group

Figures 6.40 and 6.41 above indicate that SNT was perceived to be negative in that it did not comply with regulatory requirements; in particular, overdue RBI vessels, pipelines and pressure safety valves were perceived to be very low. This was supported by the level of absenteeism and injuries that were perceived to be low. The visual planning system, capacity planning system and performance management system were also perceived to be very low.

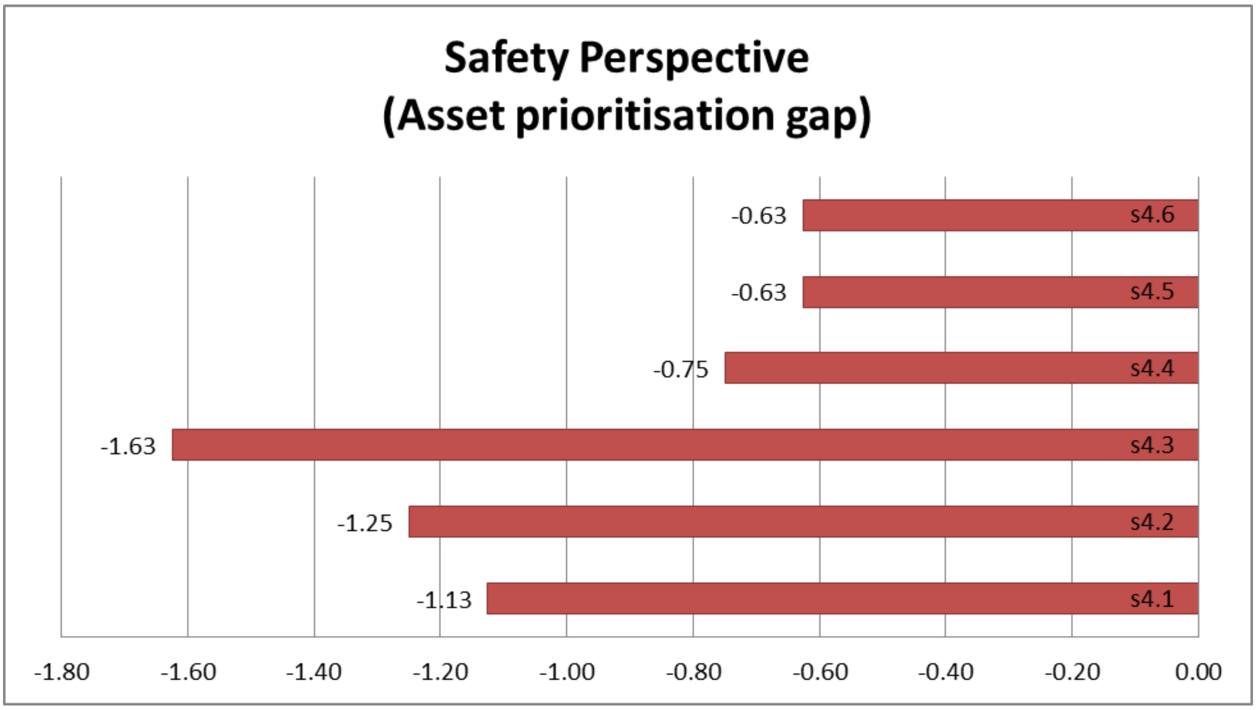

Figure 6.42 Gap analysis of safety perspective for the Production Group

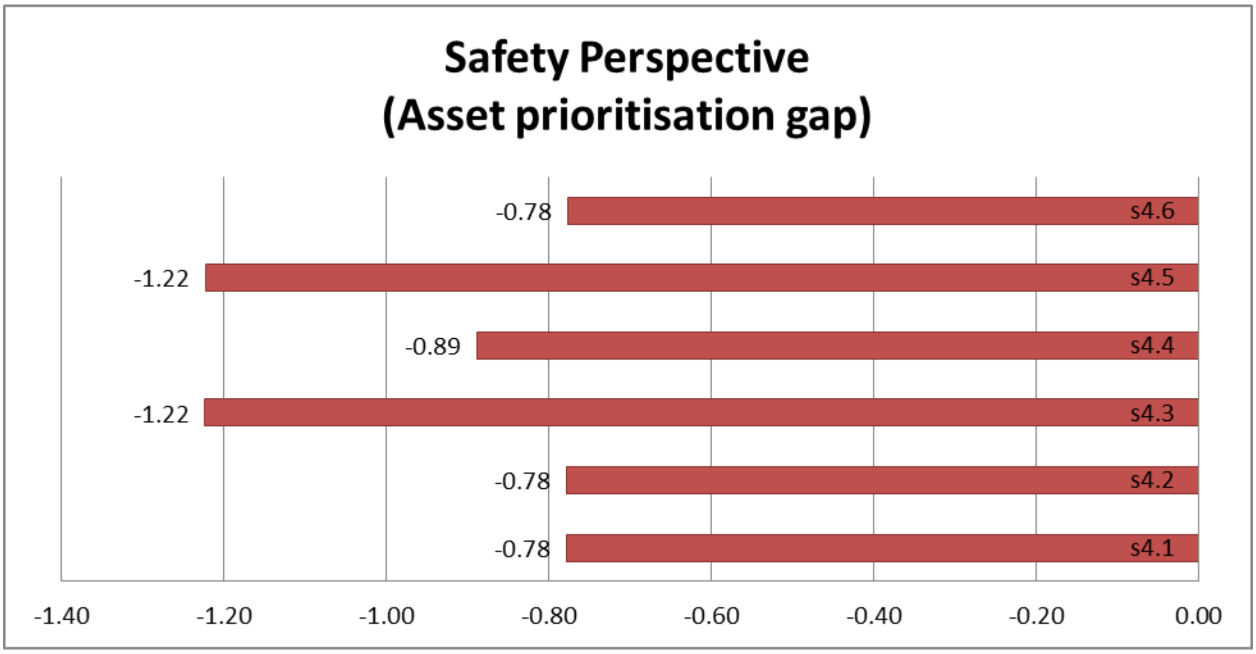

Figure 6.43 Gap analysis of safety perspective for the Maintenance Group

Figures 6.42 and 6.43 above indicate that SNT was perceived to have very high minor injuries, product spillages and overdue priority 1 incidents. This is supported by the perception that material control, support, planning and availability were also perceived to be ineffective and low.

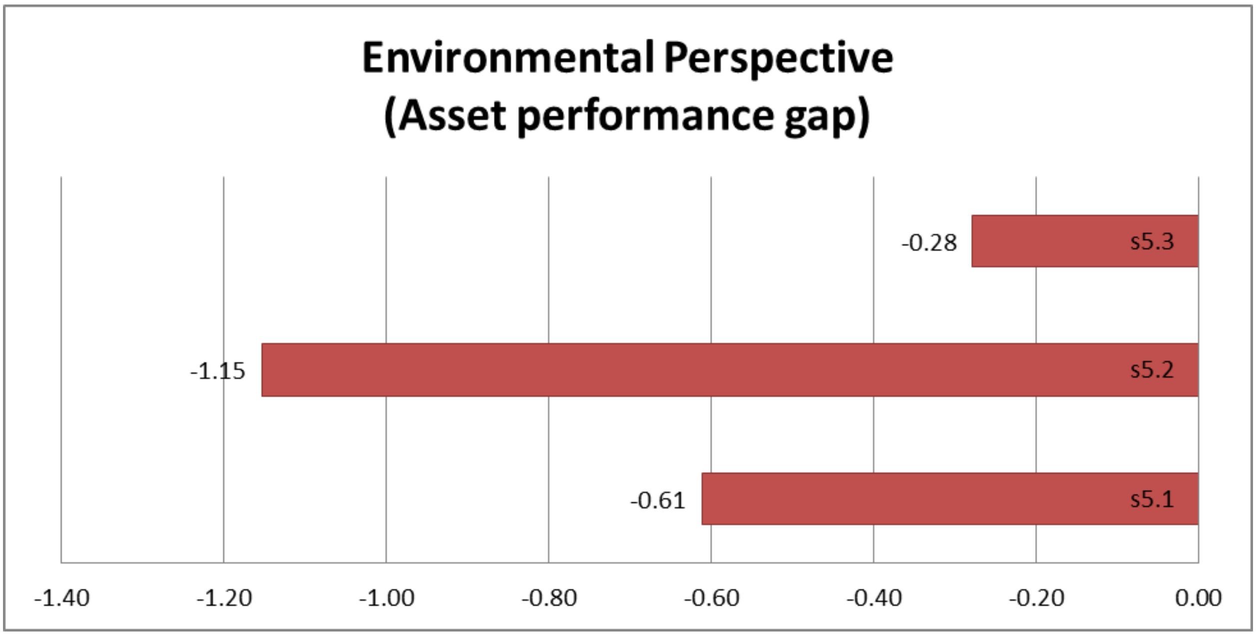

Figure 6.44 Gap analysis of environmental perspective for the Production Group

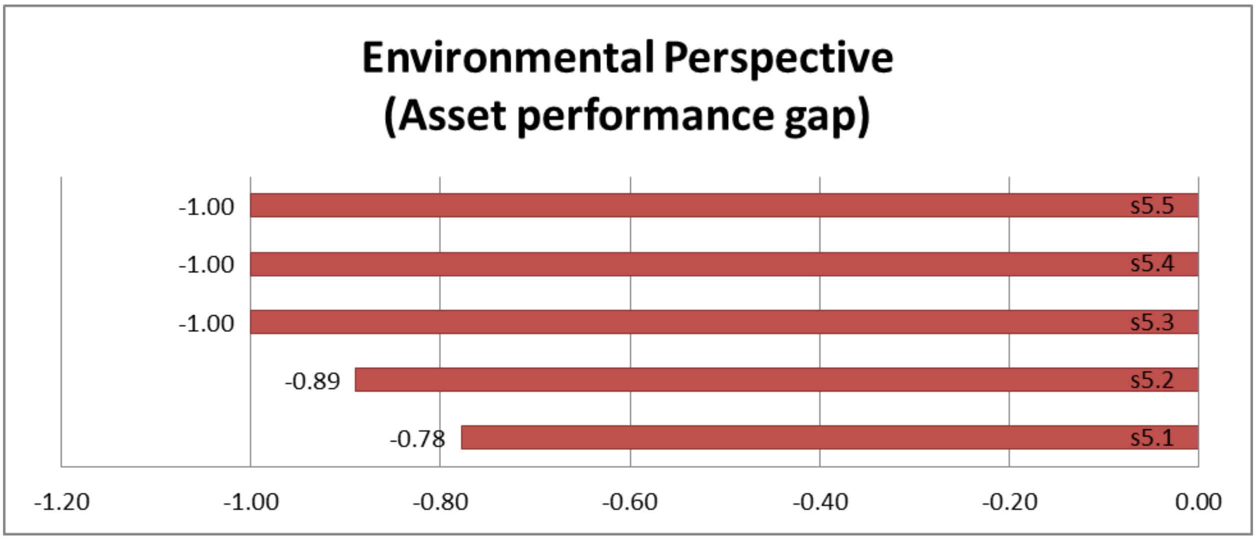

Figure 6.45 Gap analysis of environmental perspective for the Maintenance Group

Figures 6.44 and 6.45 above indicate that SNT was perceived to be negative or low on cross training of artisans, operators, supervisors, technicians, engineers and inspectors. Further perceptions are that the work prioritisation system was not effective, resource planning and allocation were low and scheduled jobs were not completed on time.

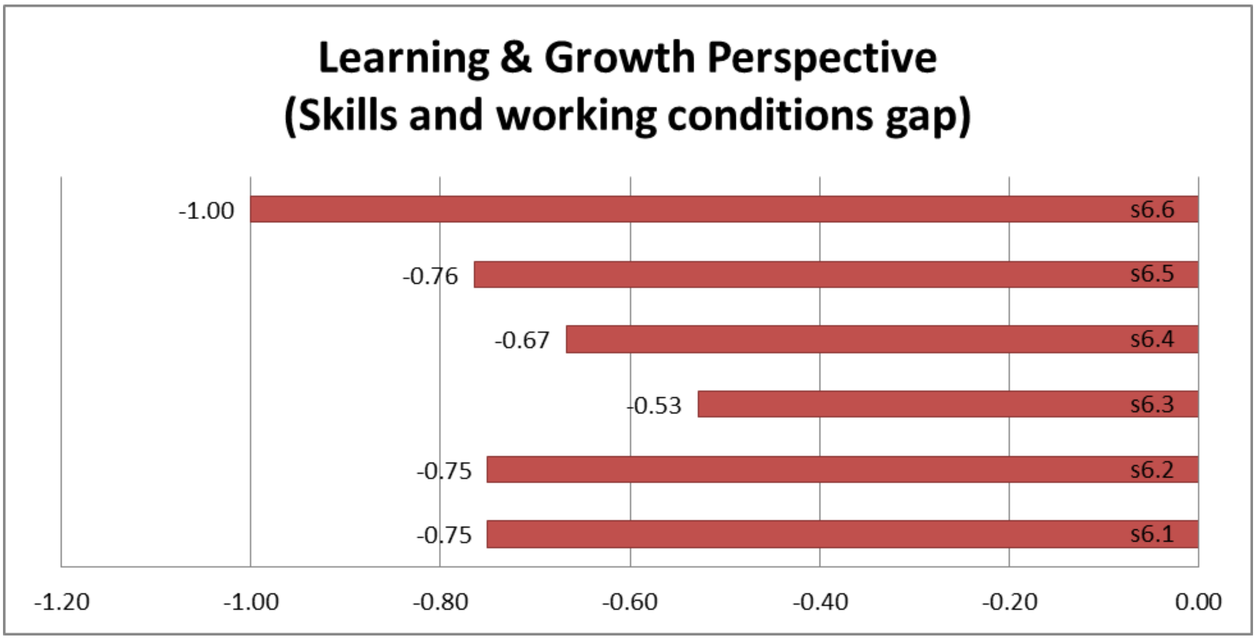

Figure 6.46 Gap analysis of learning and growth for the Production Group

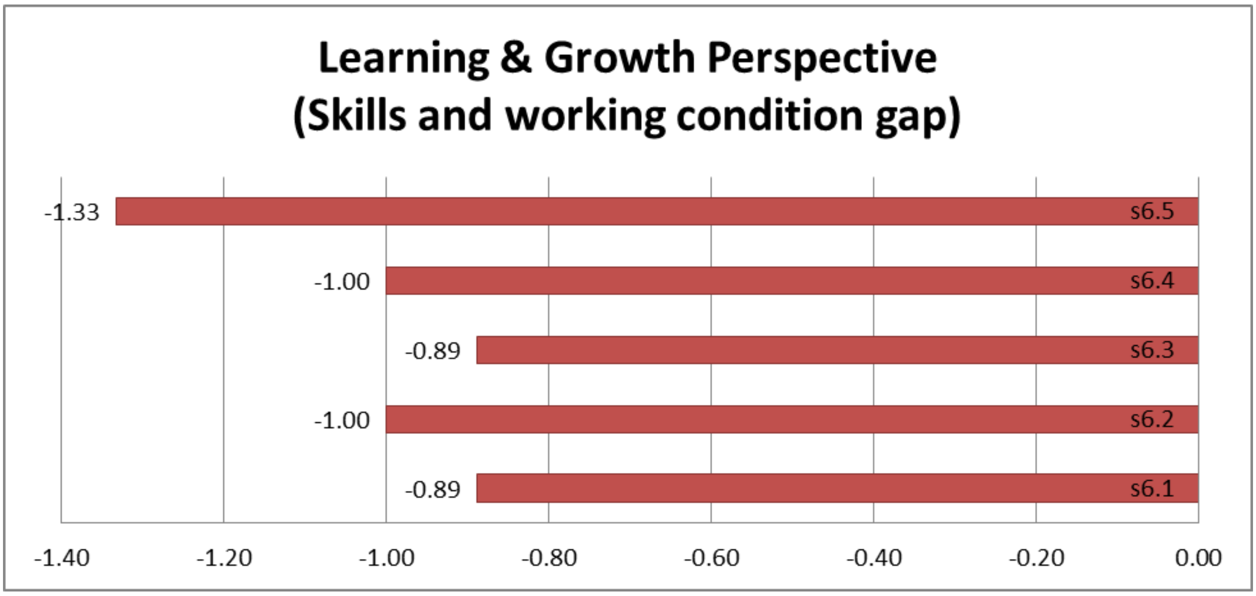

Figure 6.47 Gap analysis of learning and growth perspective for the Maintenance Group

In Figures 6.46 and 6.47 above, production perspective was perceived to be the highest in that plant and equipment were not producing according to the designed capacity. This is supported by the negative perception on the organisational structure and size in terms of the supervisors being overloaded with administrative work and the cross training of personnel was very low. It is evident that on average, expectations exceed perceptions.

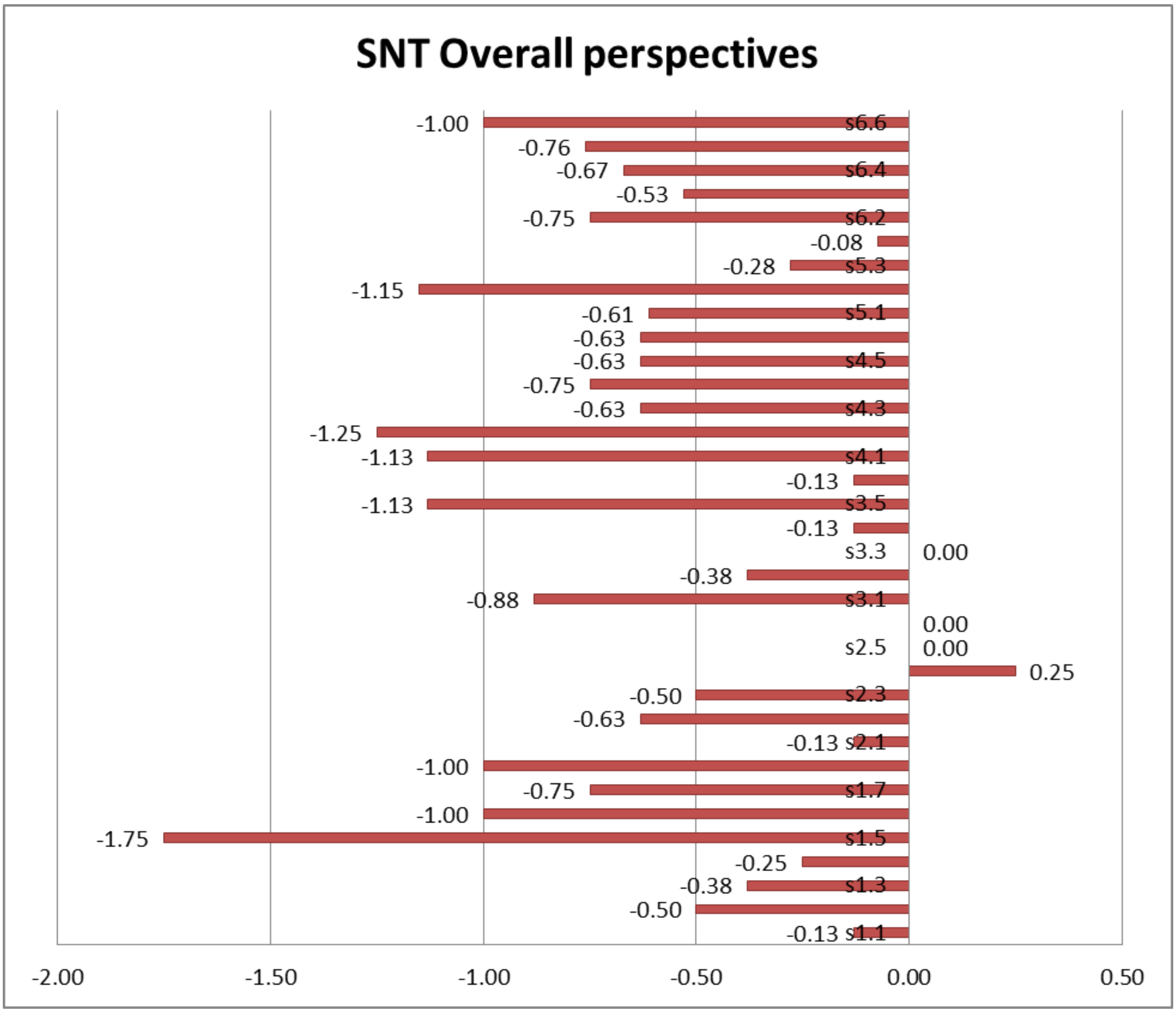

Figure 6.48 Overall dimensions gap analysis for the Production Group

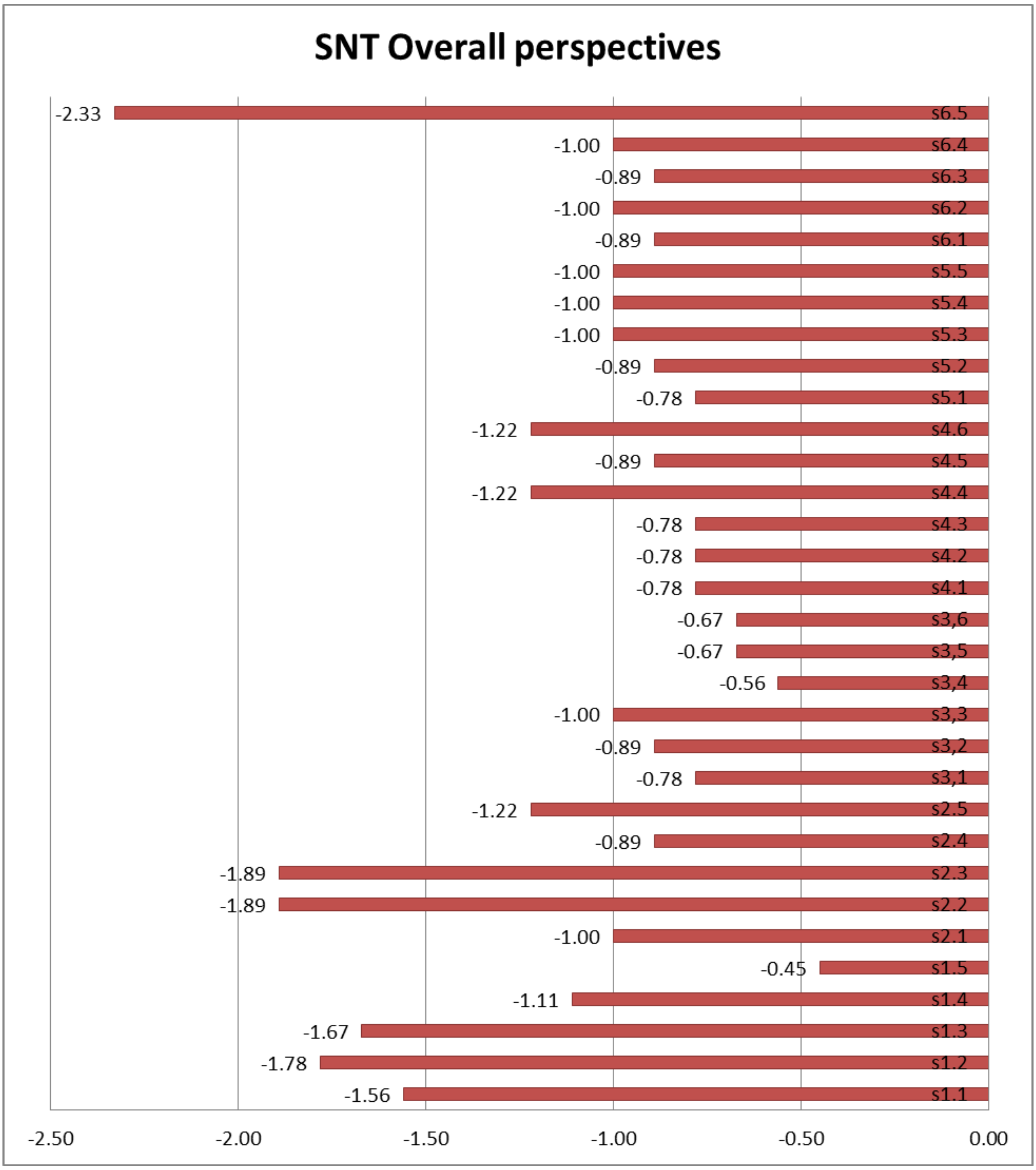

Figure 6.49 Overall dimensions gap analysis for the Production Group

According to the data displayed in Figures 6.48 and 6.49 above, plant and equipment were not producing according to the designed capacity. This is supported by the negative perception on the organisational structure and size in terms of the supervisors being overloaded with administrative work and the cross training of personnel was very low. It is evident that on average, expectations exceed perceptions.

6.4.4 Gap analysis: Refinery (REF)

Figures 6.50 and 6.63 below represent the MS gap analysis for the six dimensions of the PO&P for REF. Appendices I and S display the PO&P gap for all six dimensions (perspectives) for REF.

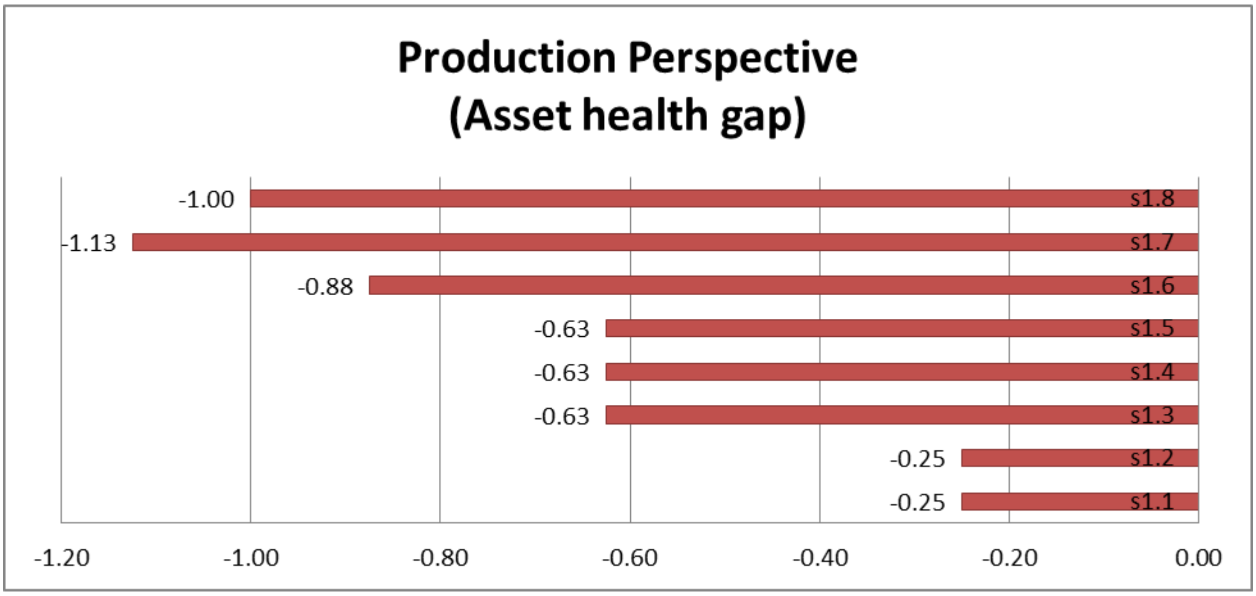

Figure 6.50 Gap analysis of production perspective for the Production Group

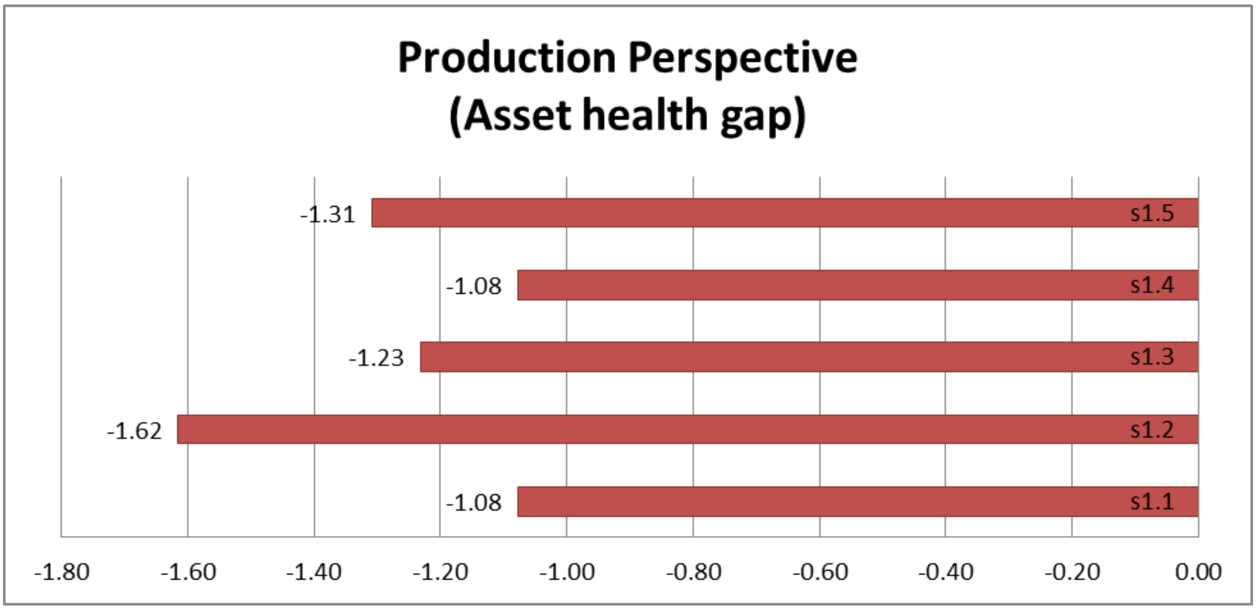

Figure 6.51 Gap analysis of production perspective for the Maintenance Group

Figures 6.50 and 6.51 above indicate that REF was perceived to be negative in that compilation, approval and communication of production plans and schedules to all relevant stakeholders is ineffective. It is perceived that daily, weekly and monthly PO was not within the scheduled or planned targets, plant and equipment were not operated per design capacity, plant and equipment were not available, reliable, operable and efficient after the execution of maintenance activities. The organisational structure and size is perceived to be negative in that decisions were confined to executive management, cross training of technical staff was ineffective and communication channels are obstructed by “red tape” which delays decisions and the flow of information.

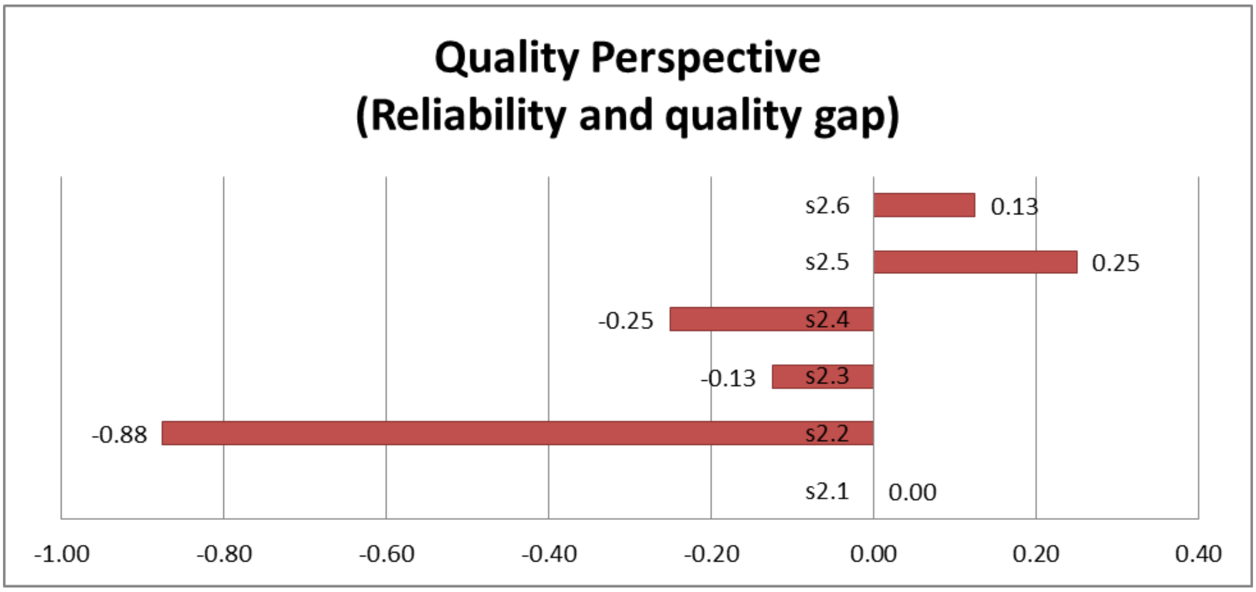

Figure 6.52 Gap analysis of quality perspective for the Production Group

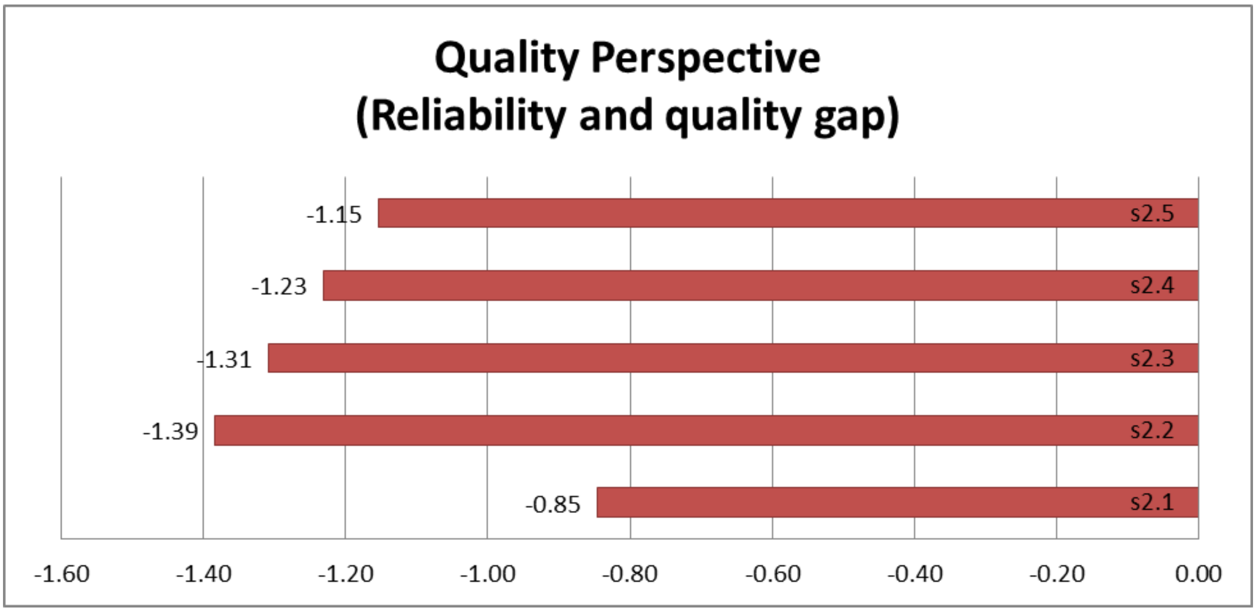

Figure 6.53 Gap analysis of quality perspective for the Maintenance Group

Figures 6.52 and 6.53 above indicate that REF was perceived to have high reworks based on production and maintenance activities and that skills and cross training of personnel was low. It is also perceived that CMMS was not properly and fully utilised in terms of data capturing, retrieval and user friendliness.

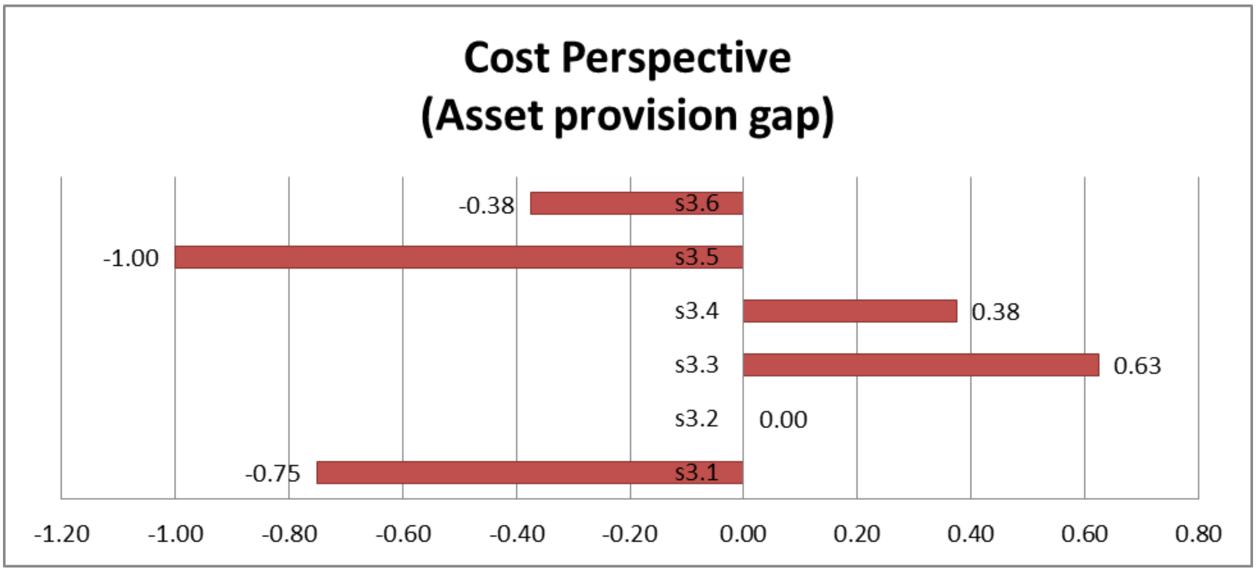

Figure 6.54 Gap analysis of cost perspective for the Production Group

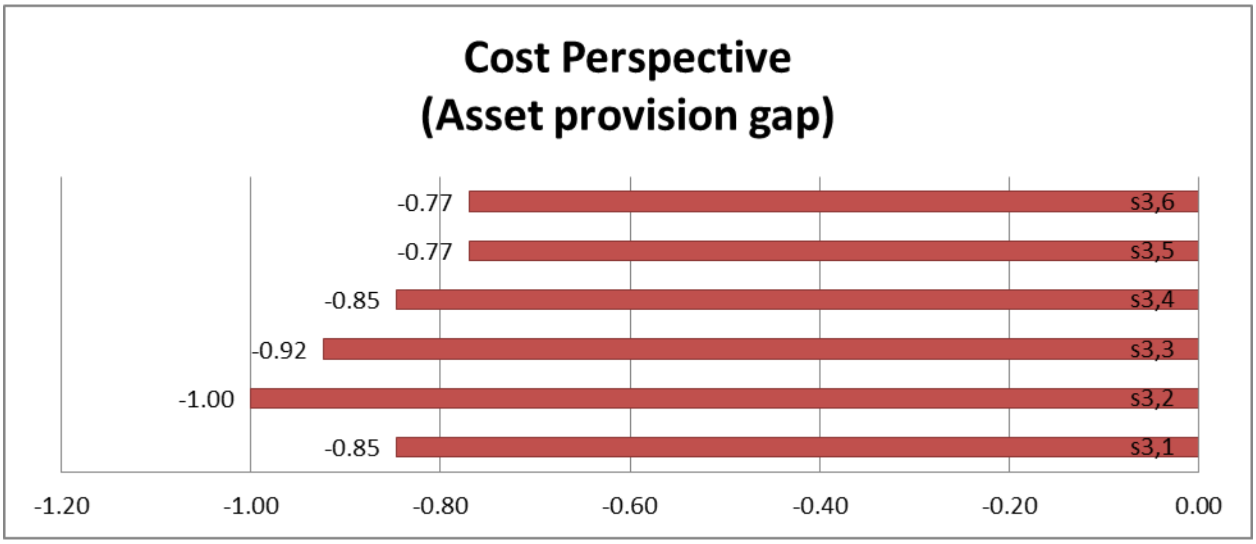

Figure 6.55 Gap analysis of cost perspective for the Maintenance Group

Figures 6.54 and 6.55 above indicate that REF was perceived to be losing income and revenue due to low production volumes. This is supported by the perception that work planning was ineffective in that shutdown work was not planned in advance (long range planning) and the planning concept was not embraced by supervisors. However, this is not supported the perception that product prices were not reduced due to poor quality and production reworks.

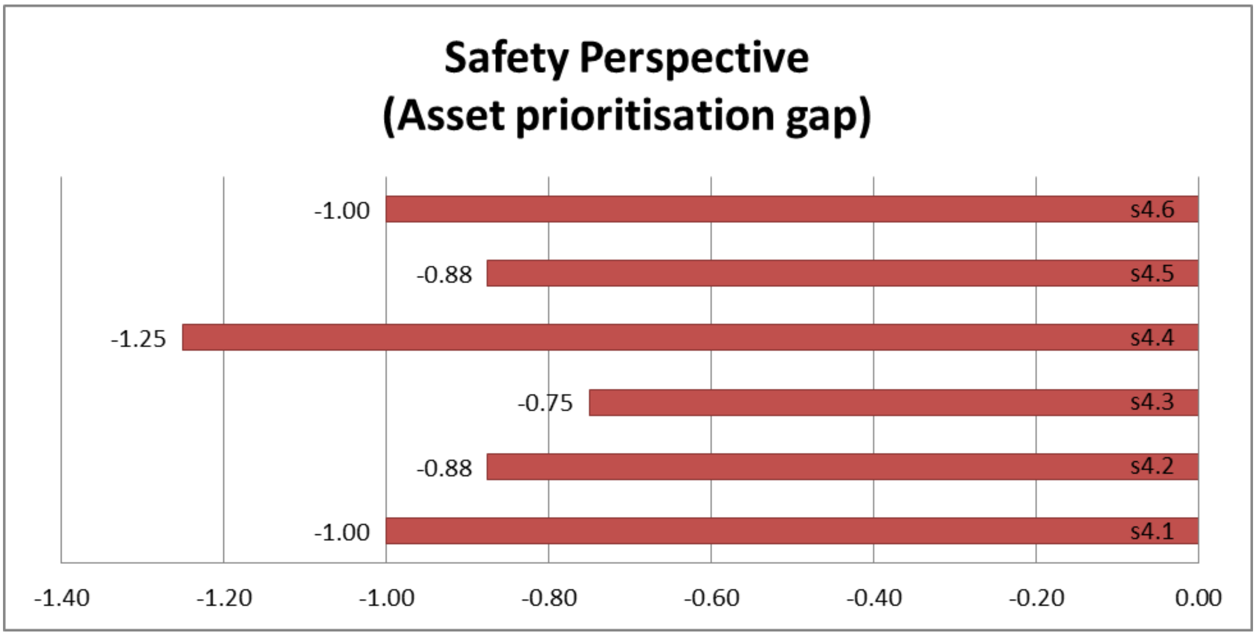

Figure 6.56 Gap analysis of safety perspective for the Production Group

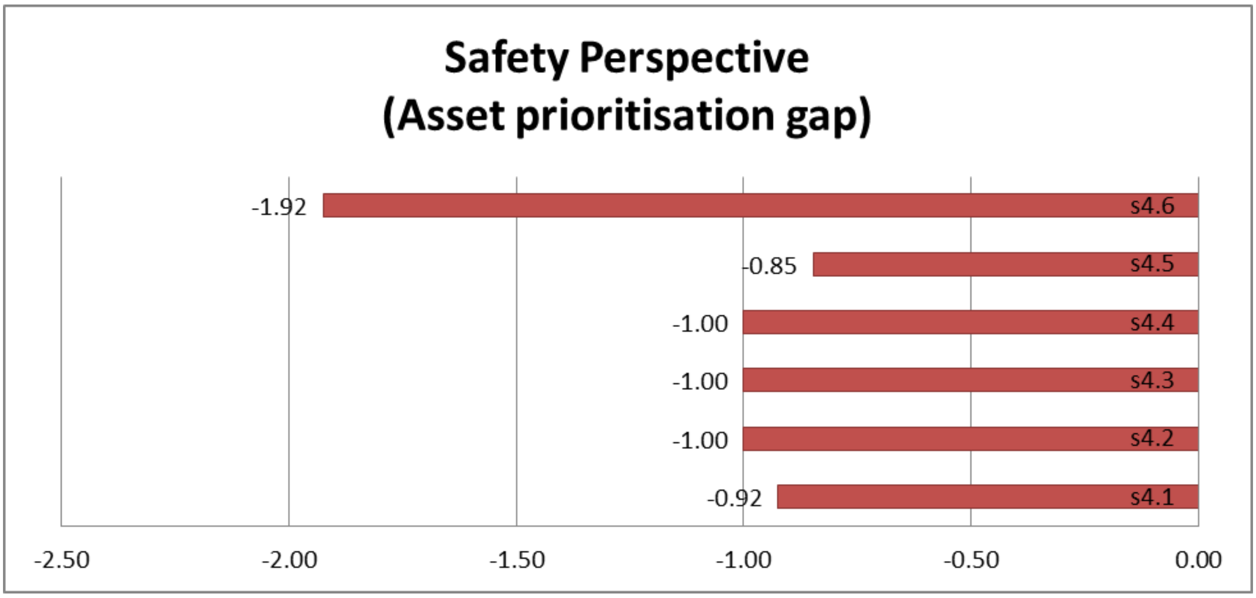

Figure 6.57 Gap analysis of safety perspective for the Maintenance Group

Figures 6.56 and 6.57 above indicate that REF was perceived to be negative in that it did not comply with regulatory requirements, especially overdue RBI vessels, pipelines and pressure safety valves. This is supported by the perception that maintenance work measurement was not effectively and efficiently exercised, in that capacity plans, KPI reports and the visual planning system were very low.

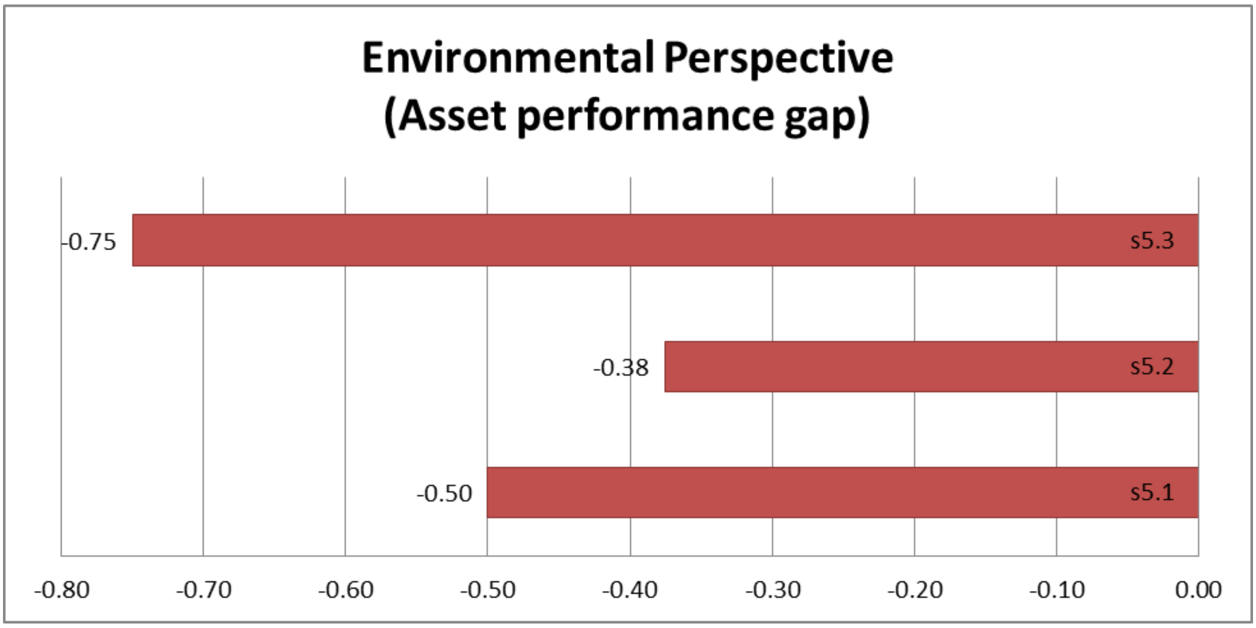

Figure 6.58 Gap analysis of environmental perspective for the Production Group

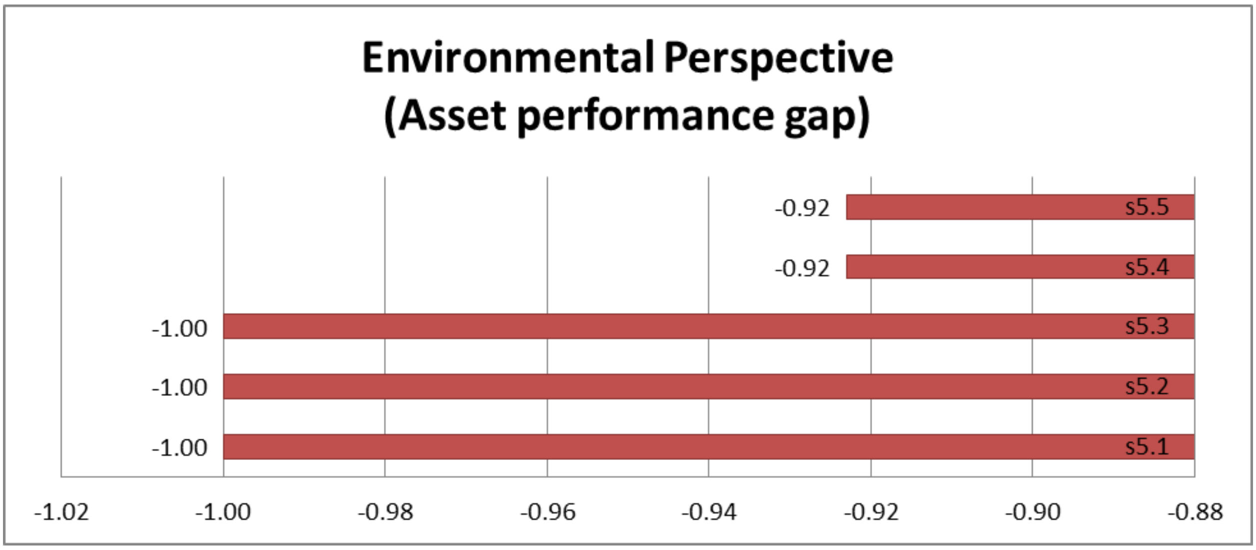

Figure 6.59 Gap analysis of environmental perspective for the Maintenance Group

Figures 6.58 and 6.59 above indicate that REF was perceived to be in contravention of the regulatory requirements in that product spillages and the overdue priority 1 incidents were very high. This is supported by the perception that material control and support was low, in that a part numbering system was not in place, stock levels were not defined and usage records were not available to setup order quantities.

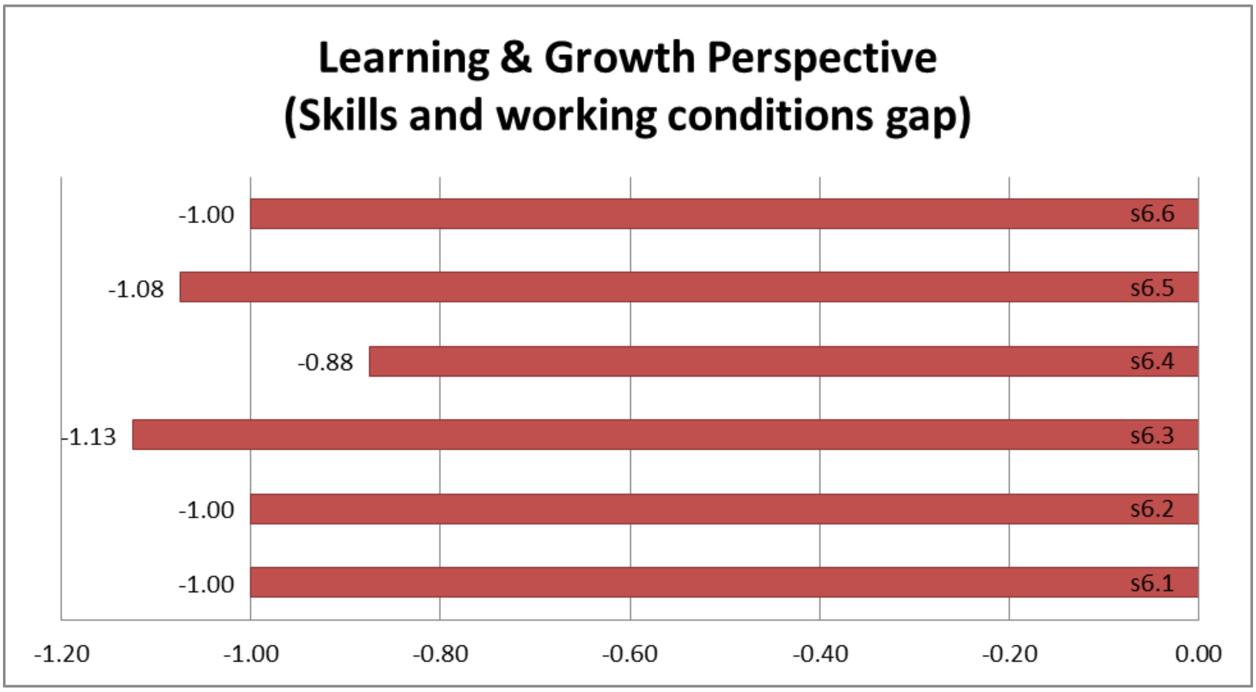

Figure 6.60 Gap analysis of learning and growth for the Production Group

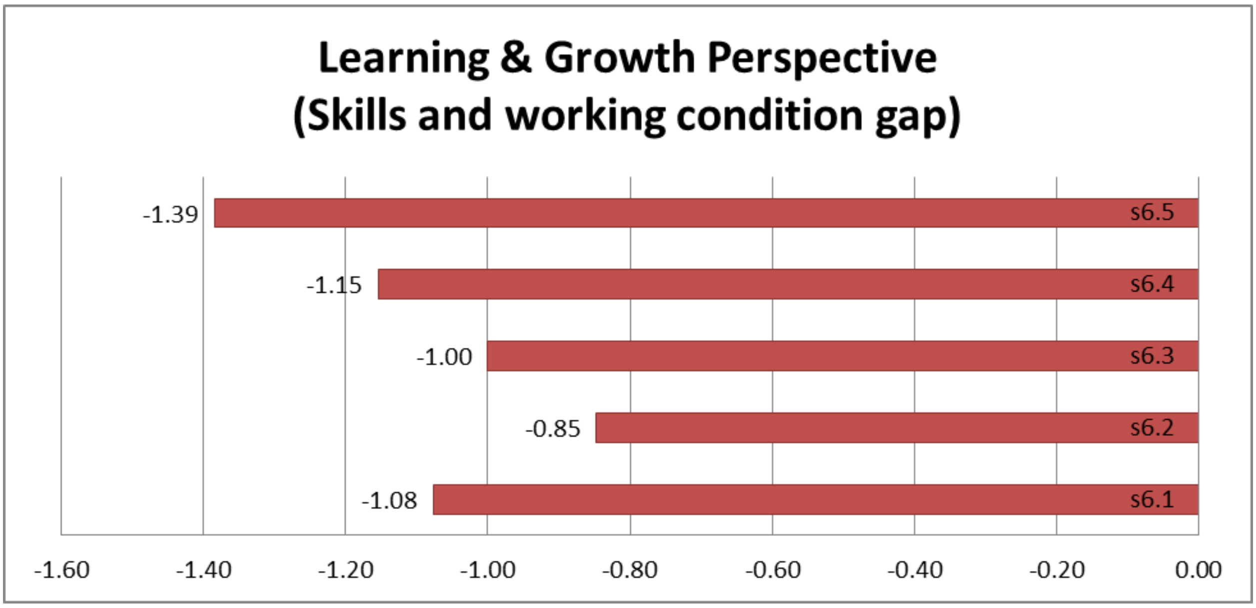

Figure 6.61 Gap analysis of learning and growth perspective for the Maintenance Group

Figures 6.60 and 6.61 above indicate that REF was perceived to be negative or low on cross training of artisans, operators, supervisors, technicians, engineers and inspectors. This is supported by the perception that the work prioritisation system was not effective, resource planning and allocation was low and scheduled jobs were not completed on time.

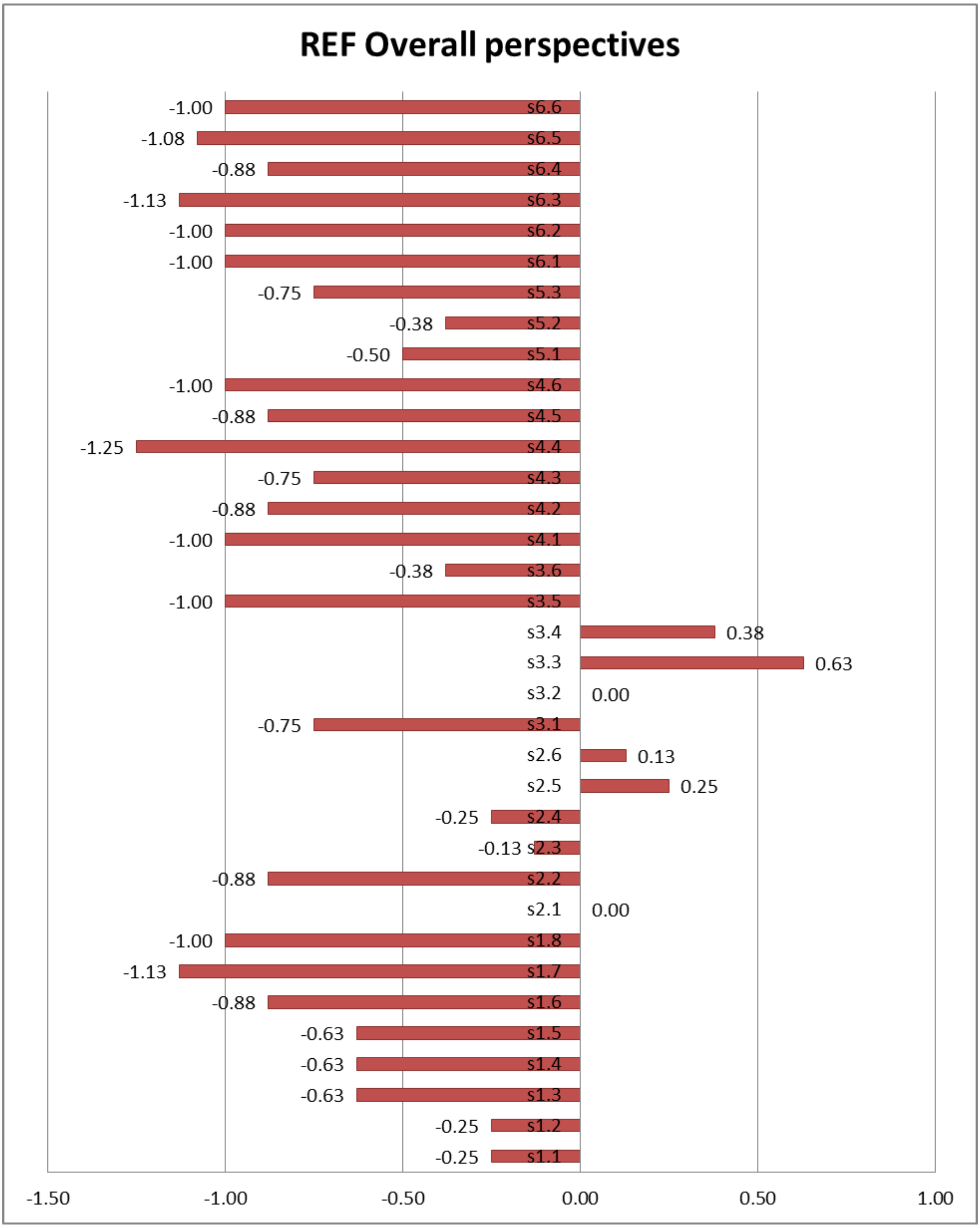

Figure 6.62 Overall dimensions gap analysis for the Production Group

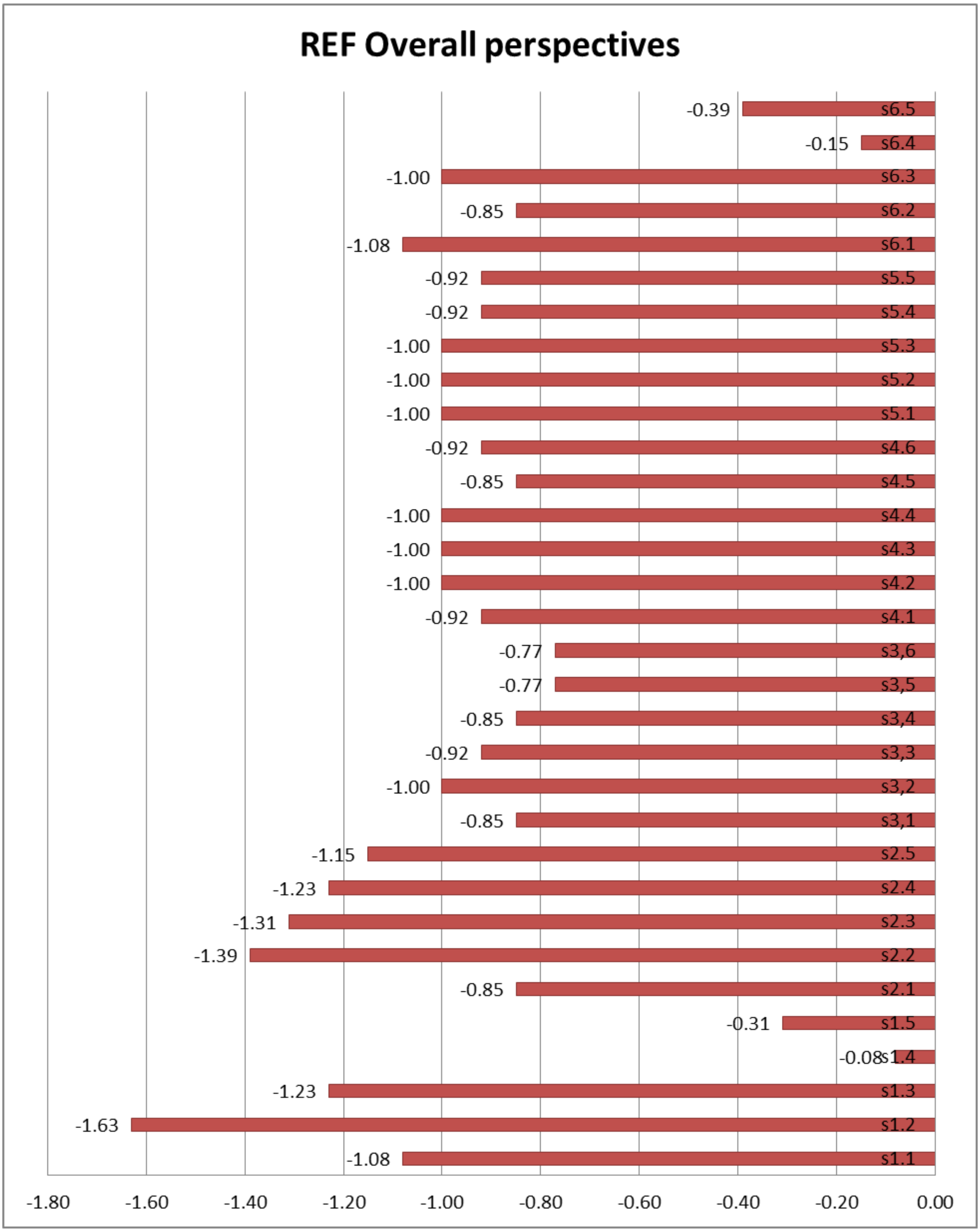

Figure 6.63 Overall dimensions gap analysis for the Production Group

According to the data displayed in Figures 6.62 and 6.63 above, the safety perspective was perceived to be the lowest in that minor injuries were very high. This is followed by the perception that plant and equipment was not always reliable, available, operable and efficient after executing maintenance work. The other high dimension is the perception that the supervisors were overloaded with administrative work and that the maintenance information was not available and/or reliable. It is evident that on average, expectations exceeded perceptions.

6.4.5 Gap analysis: Blending and Storage (B&S)

Figures 6.64 and 6.77 below represent the MS gap analysis for the six dimensions of the PO&P for B&S. Appendices J and T display the PO&P gap for all six dimensions (perspectives) for B&S.

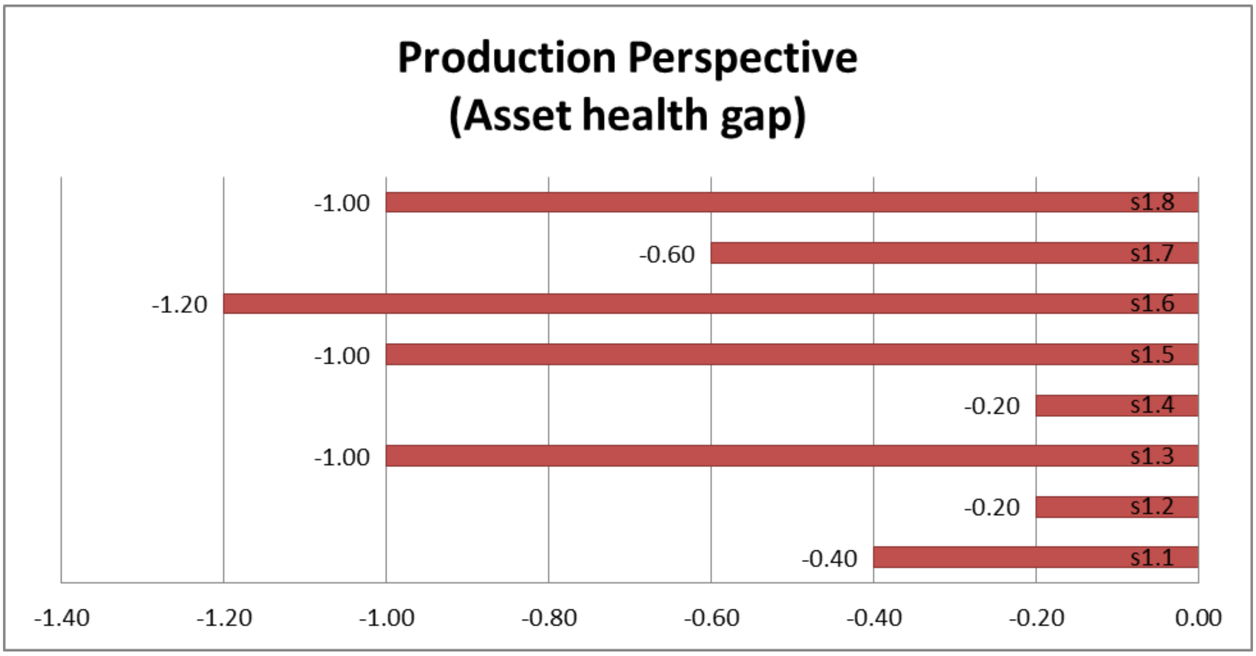

Figure 6.64 Gap analysis of production perspective for the Production Group

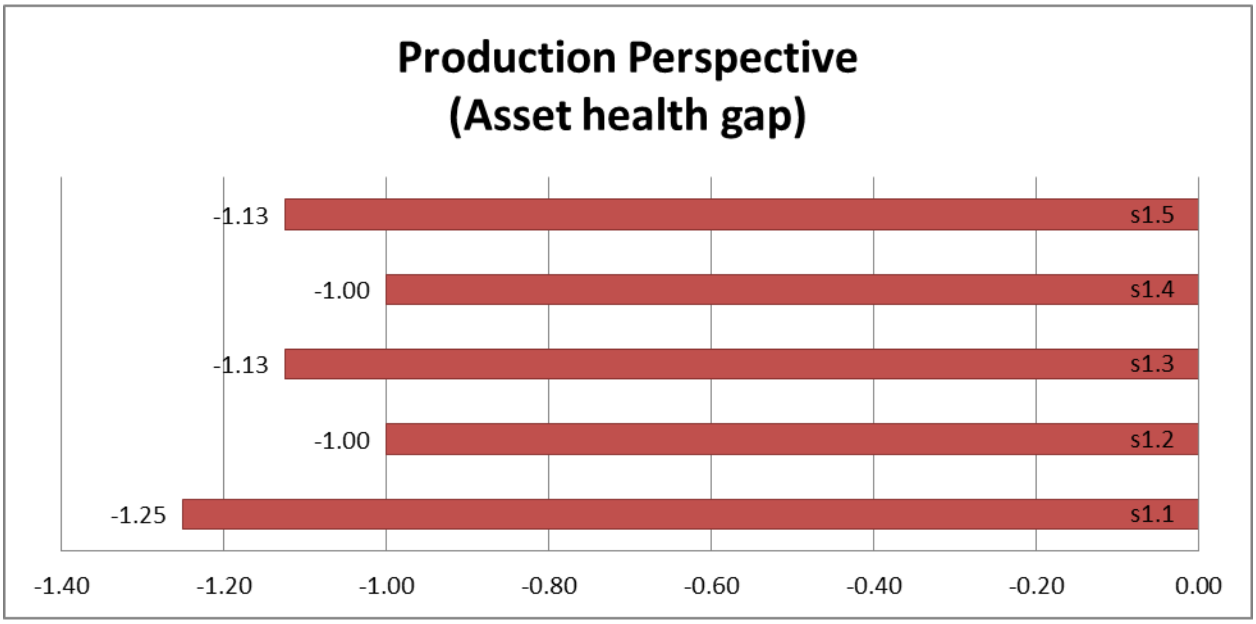

Figure 6.65 Gap analysis of production perspective for the Maintenance Group

Figures 6.64 and 6.65 above indicate that B&S was perceived to be negative in that compilation, approval and communication of production plans and schedules to all relevant stakeholders is ineffective. It is perceived that B&S does not produce according to daily, weekly and yearly targets. This is supported by the perception that plant and equipment were not always available, reliable, operable and efficient after the execution of maintenance work. Organisational structure and size was believed to be unsupportive to decision making by lower level management and communication channels were ineffective, hence the flow of information is delayed and cross functional training is low.

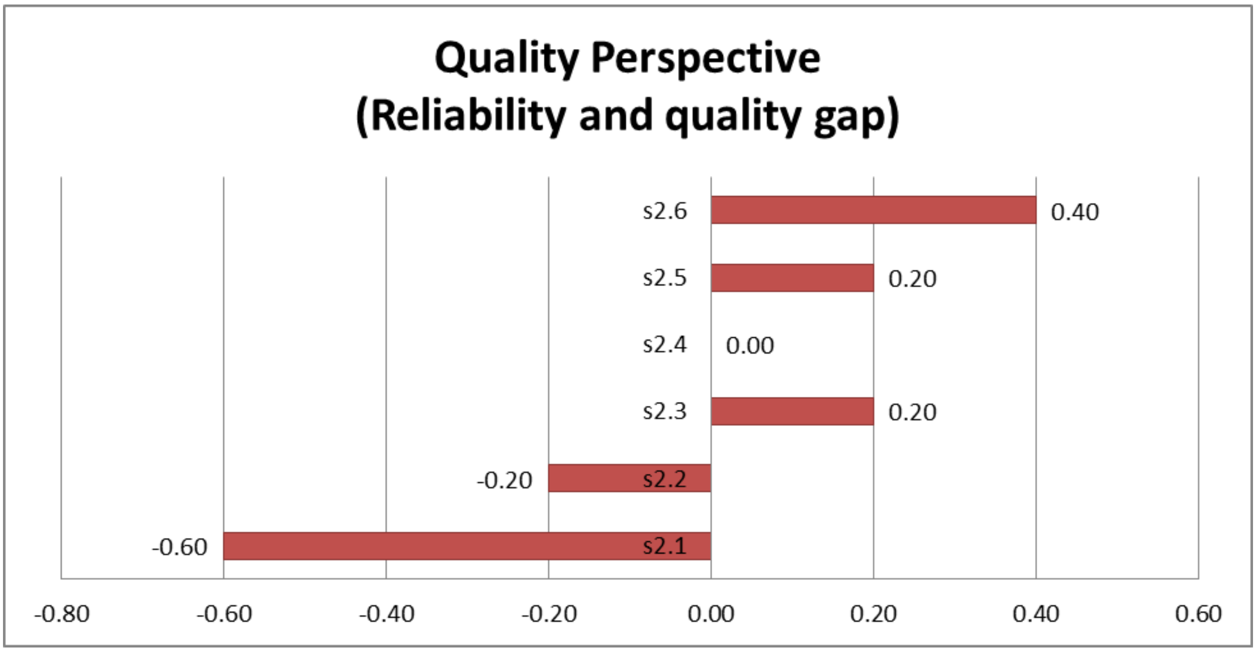

Figure 6.66 Gap analysis of quality perspective for the Production Group

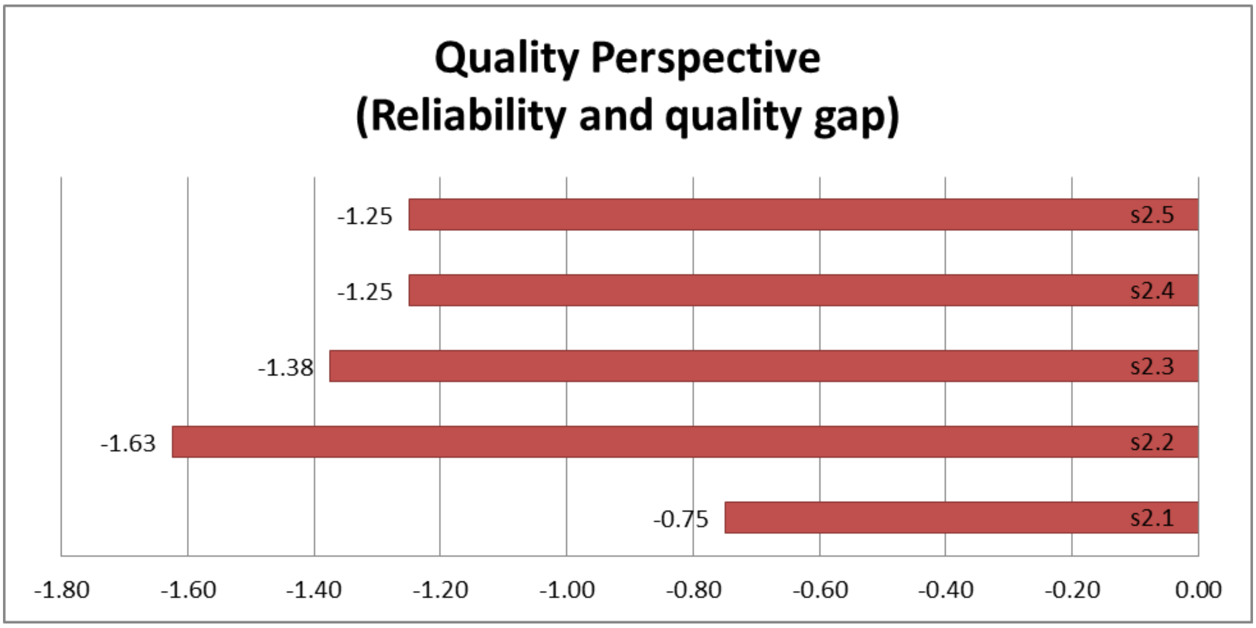

Figure 6.67 Gap analysis of quality perspective for the Maintenance Group

Figures 6.66 and 6.67 above indicate that B&S was perceived to be high in terms of maintenance and production reworks and delays. Quality of products manufactured was perceived to be low due to plant and equipment breakdowns. The implementation and use of CMMS was low hence, data, information and history were not readily available or reliable.

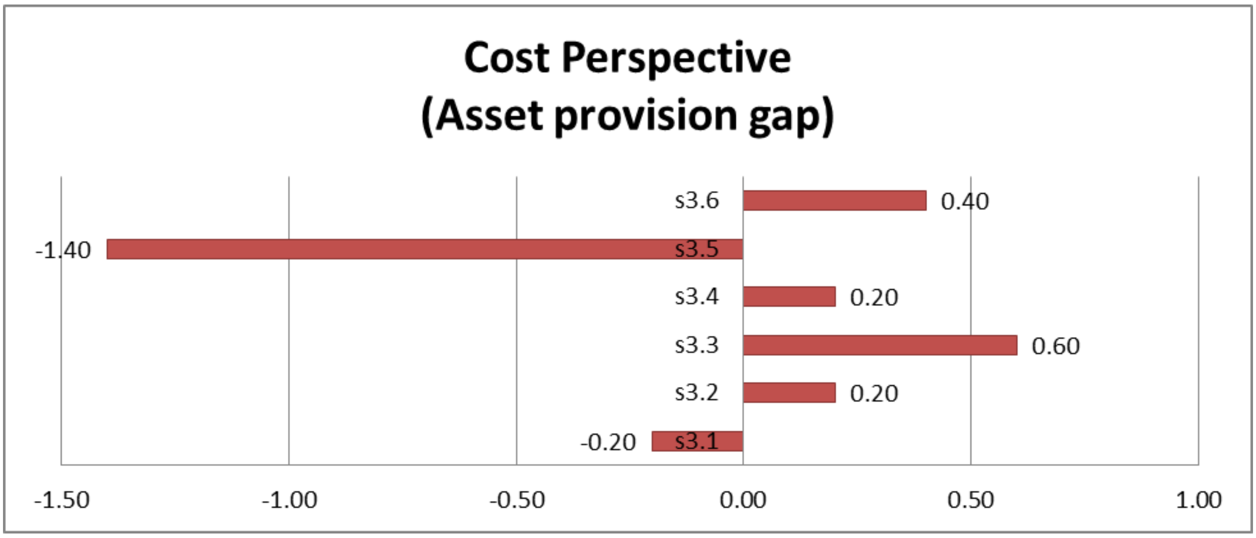

Figure 6.68 Gap analysis of cost perspective for the Production Group

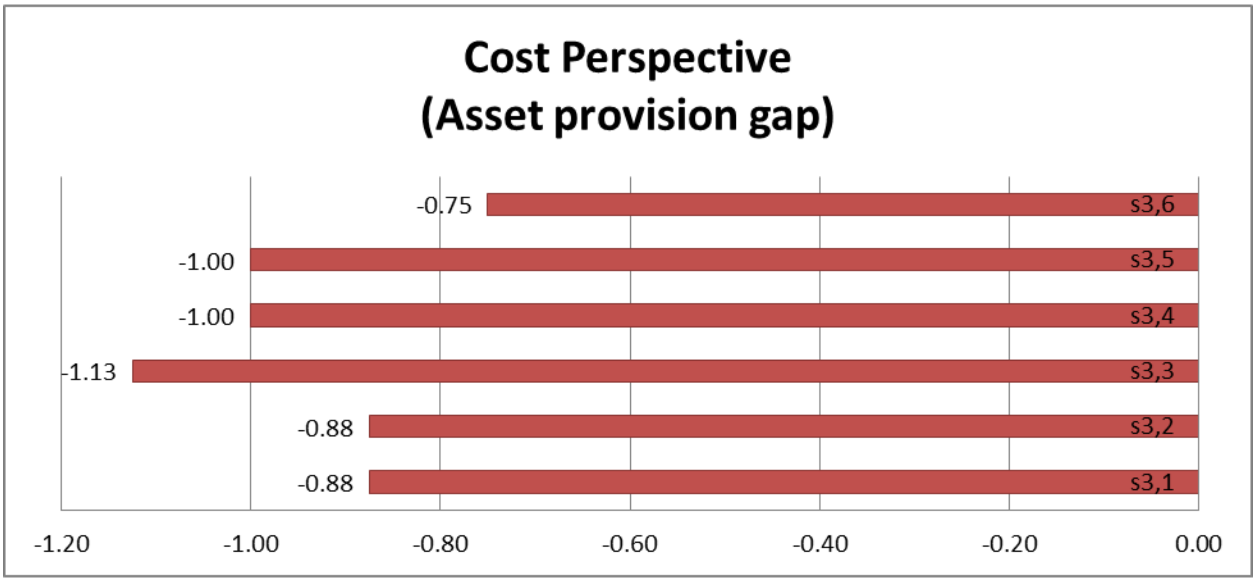

Figure 6.69 Gap analysis of cost perspective for the Maintenance Group

Figures 6.68 and 6.69 above indicate that the cost perspective of B&S was perceived to be low because the sale or delivery of products to customers was delayed by plant or equipment breakdowns. This is supported by the perception that B&S was losing revenue and income due to low production volumes. In addition, delays and look-ahead plans were not compiled, approved and communicated. However, this is supported by the perception that weekly, monthly and yearly revenue and income were not within set targets.

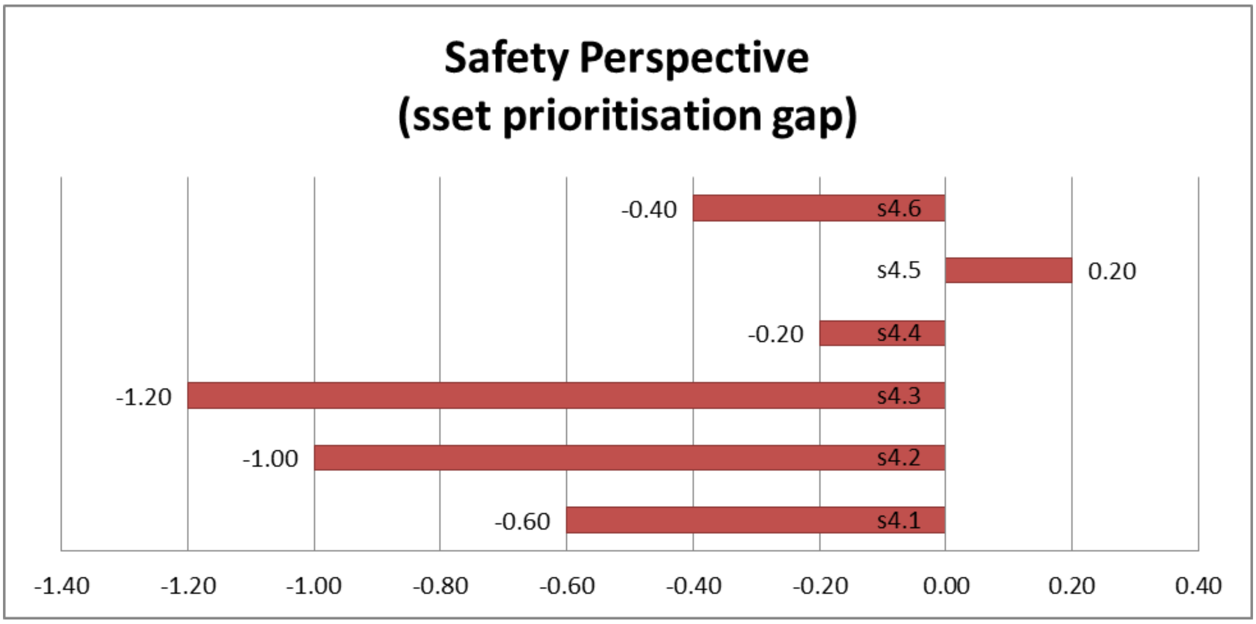

Figure 6.70 Gap analysis of safety perspective for the Production Group

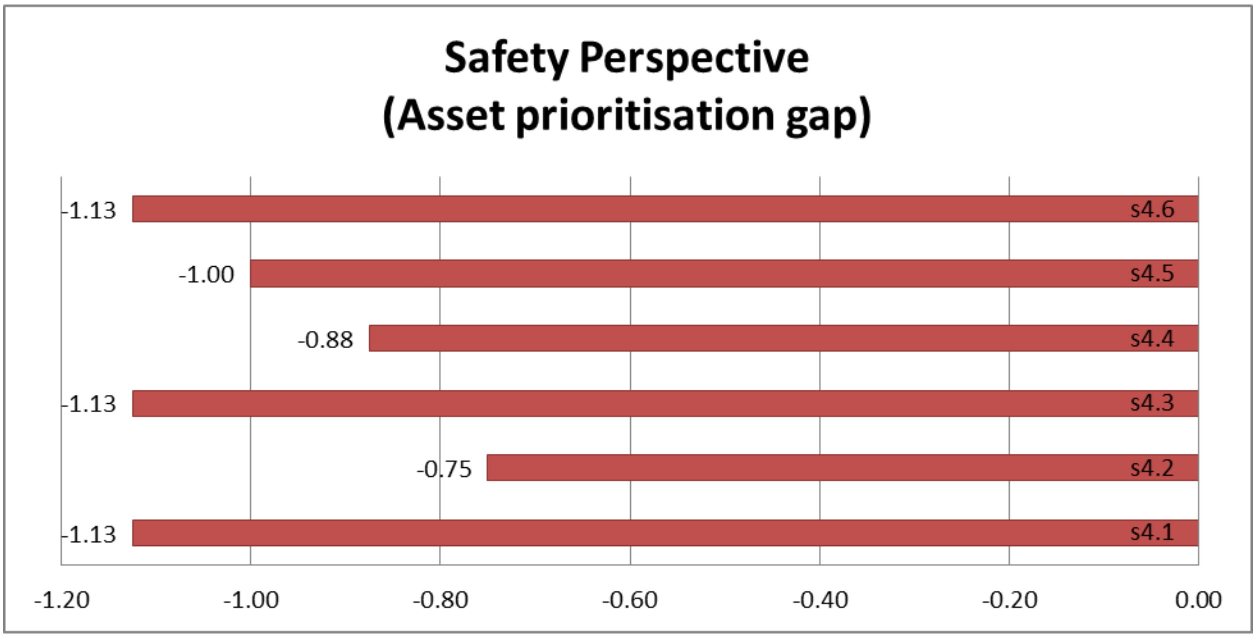

Figure 6.71 Gap analysis of safety perspective for the Maintenance Group

Figures 6.70 and 6.71 above indicate that B&S was believed to be negative, in that it did not comply with regulatory requirements, especially overdue RBI vessels, pipelines and pressure safety valves. It was also perceived that maintenance work measurement was low because the visual planning system, capacity planning system and performance management system were very low.

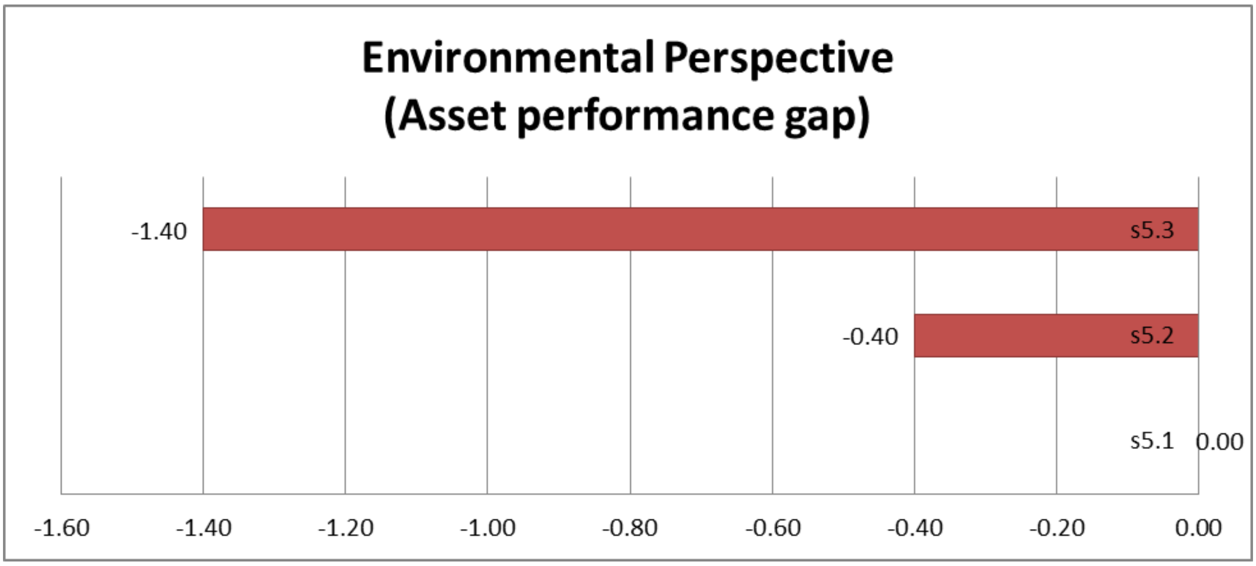

Figure 6.72 Gap analysis of environmental perspective for the Production Group

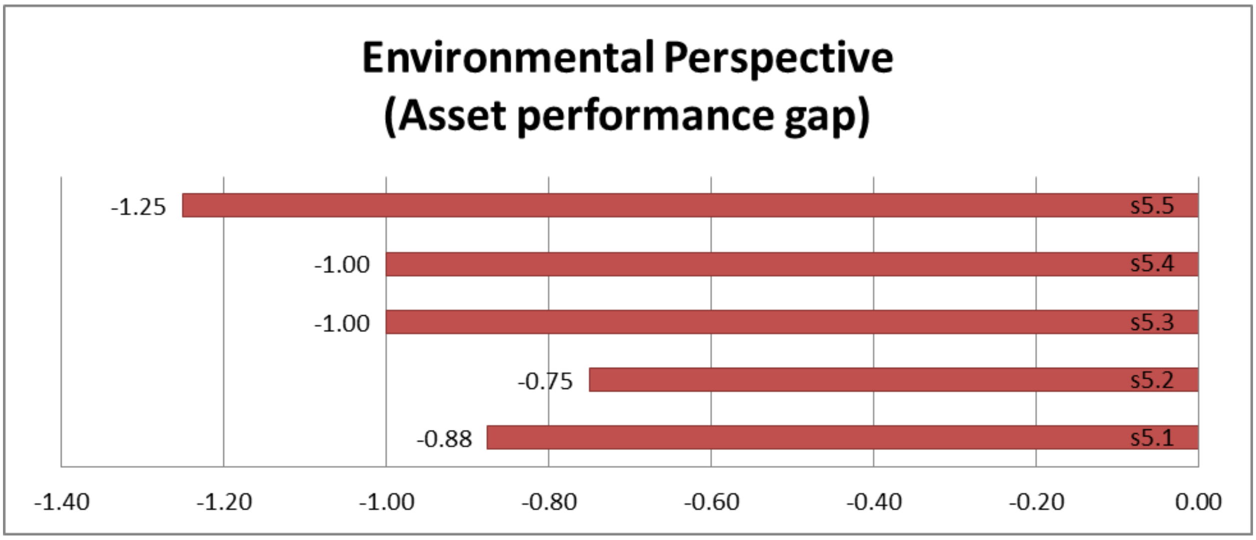

Figure 6.73 Gap analysis of environmental perspective for the Maintenance Group

Figures 6.72 and 6.73 above indicate that B&S was perceived to be non-compliant with regulatory requirements in terms of minor injuries and product spillages. Overdue priority 1 incidents were high. Material control, support, planning and availability were also perceived to be low due to lack of usage records, which are needed to setup order quantity level.

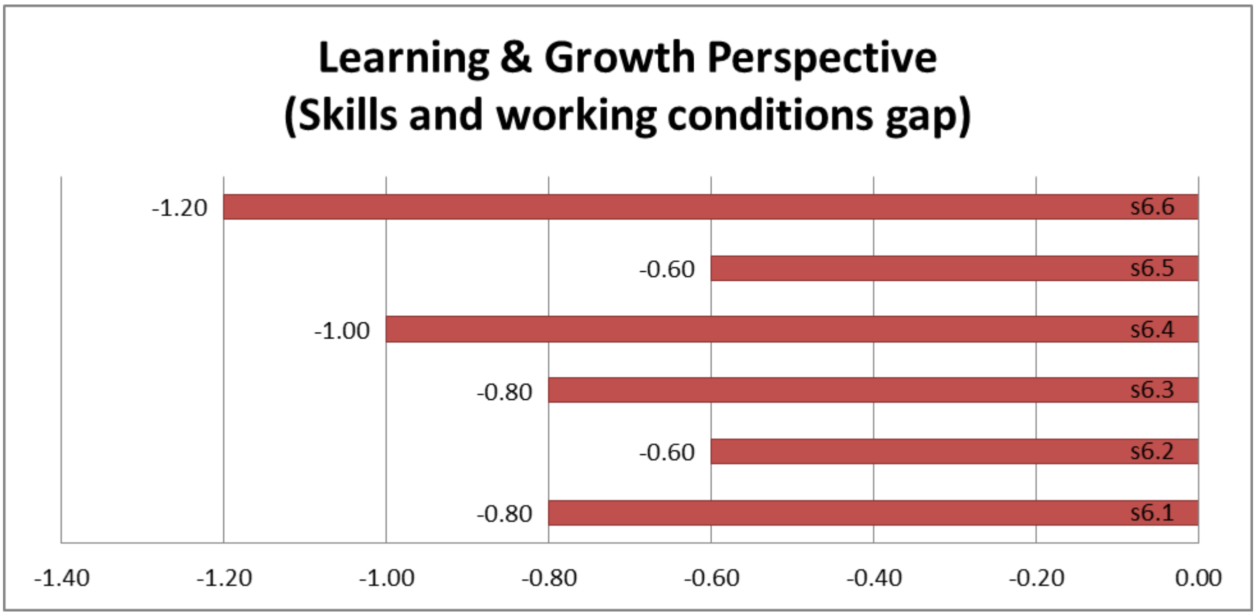

Figure 6.74 Gap analysis of learning and growth for the Production Group

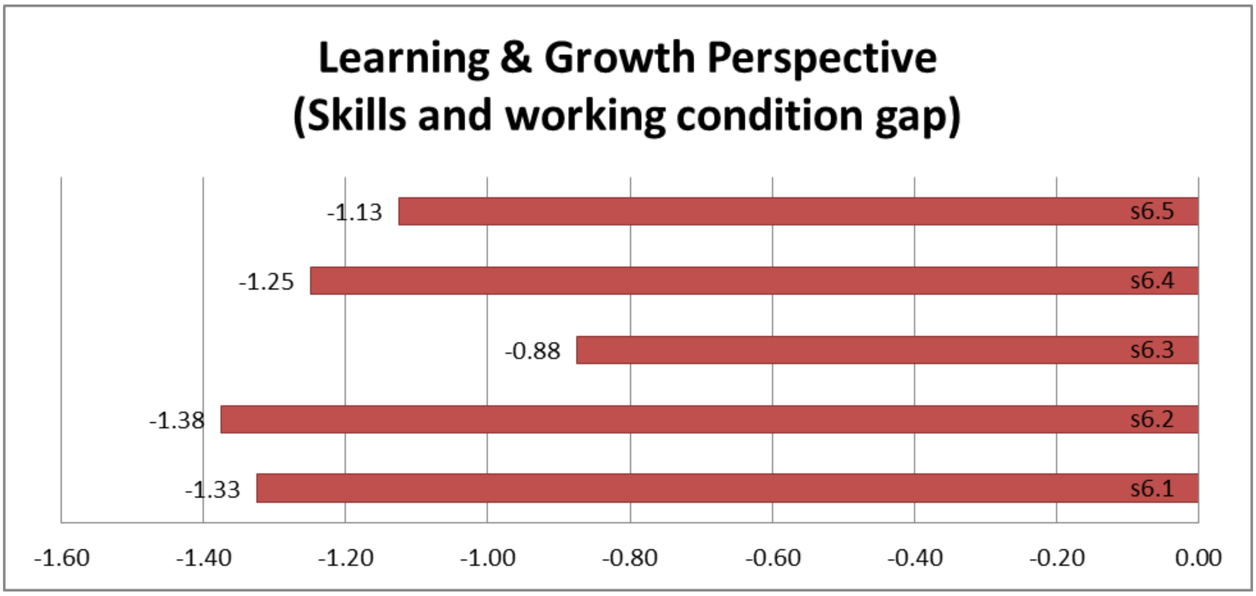

Figure 6.75 Gap analysis of learning and growth perspective for the Maintenance Group

Figures 6.74 and 6.75 above indicate that B&S was perceived to be negative or low on learning and growth due to poor (or lack of) cross training of artisans, operators, supervisors, technicians, engineers and inspectors. Further perceptions are that the work prioritisation system was not effective, resource planning and allocation were low and scheduled jobs were not completed on time.

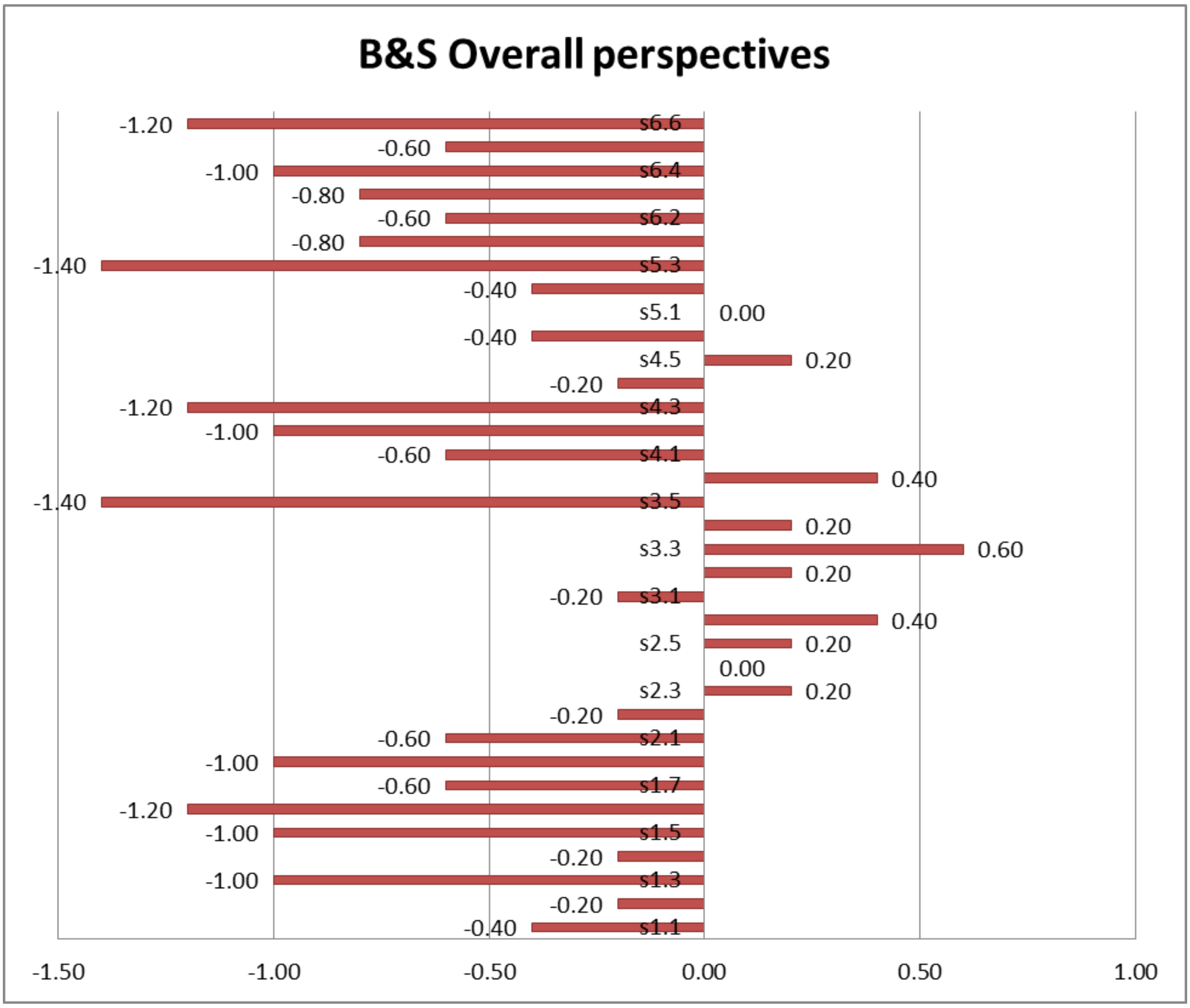

Figure 6.76 Overall dimensions gap analysis for the Production Group

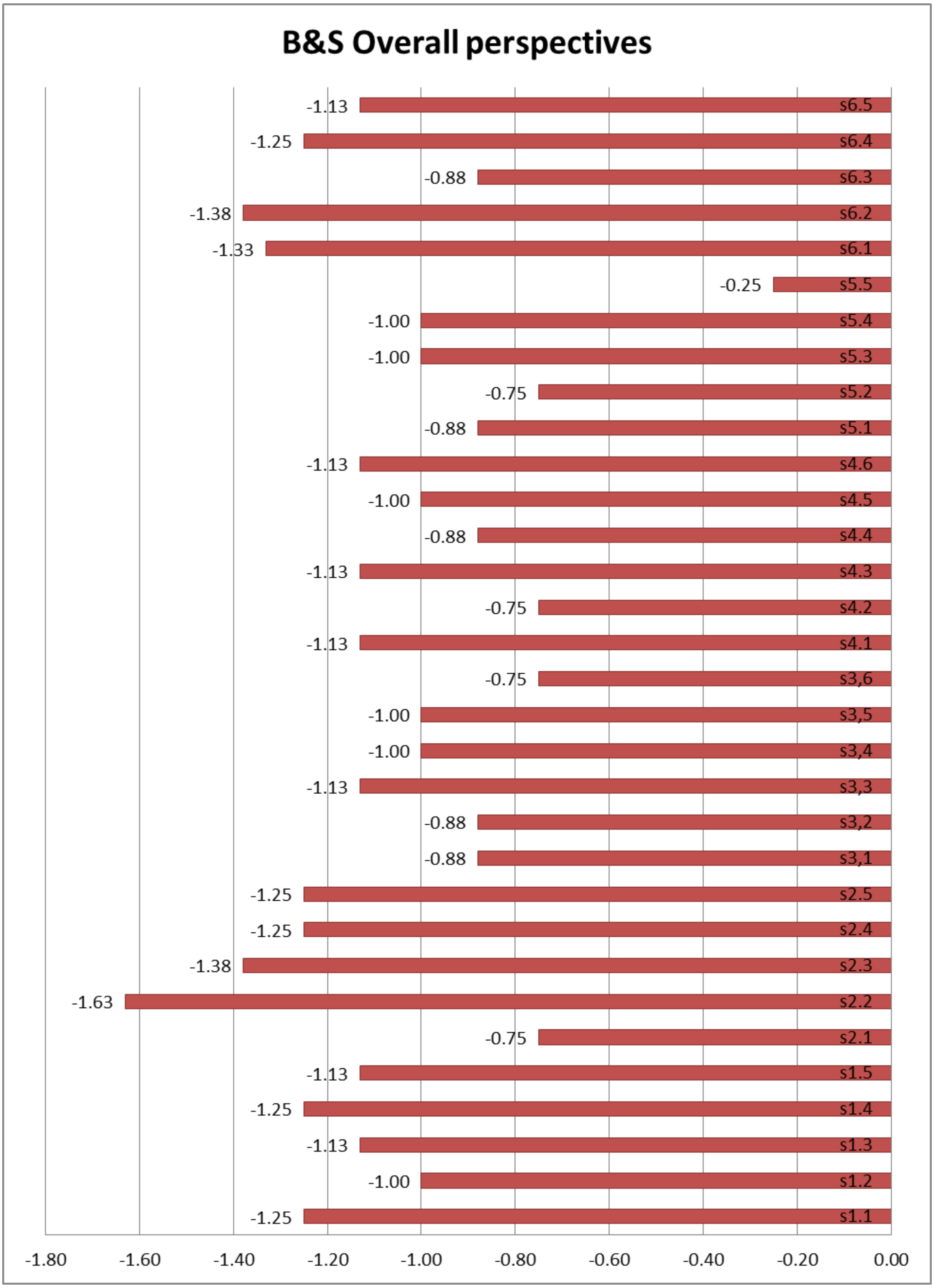

Figure 6.77 Overall dimensions gap analysis for production

According to the data displayed in Figures 6.76 and 6.77 above, the weekly, monthly and yearly revenue and income loss and the overdue priority 1 incidents were perceived to be very high. The availability, reliability, operability and efficiency of plant and equipment was perceived to be very low. Non-compliance with regulatory requirements in terms of absenteeism and RBI inspections were also perceived to be high. On average, expectations exceeded perceptions.

6.4.6 Gap analysis: Offsites and utilities (O&U)

Figures 6.78 and 6.91 below represent the MS gap analysis for the six dimensions of the PO&P for O&U. Appendices K and U display the PO&P gap for all six dimensions (perspectives) for O&U.

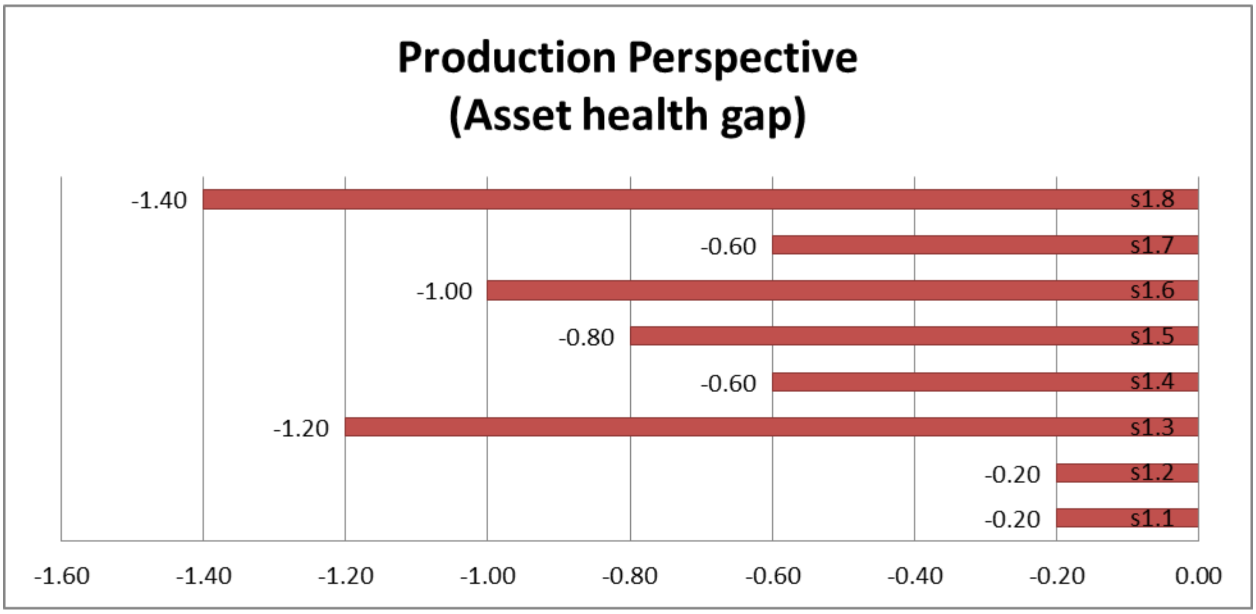

Figure 6.78 Gap analysis of production perspective for the Production Group

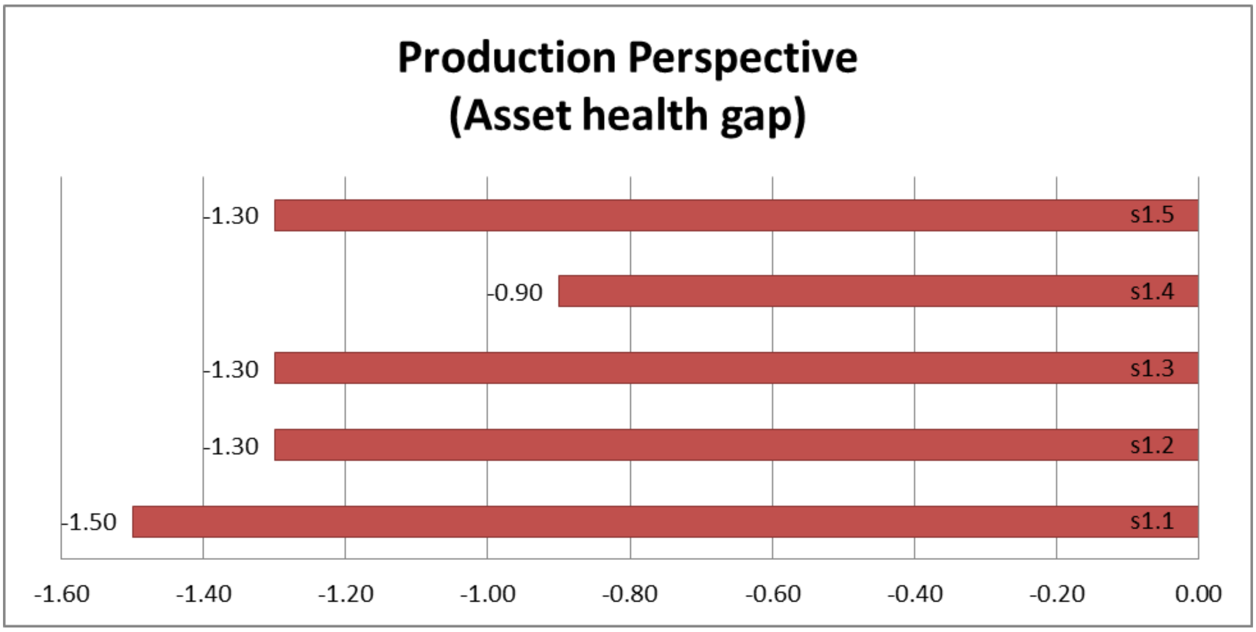

Figure 6.79 Gap analysis of production perspective for the Maintenance Group

Figures 6.78 and 6.79 above indicate that O&U was perceived to be negative in that the plant and equipment was always not available, reliable, operable and efficient after executing maintenance work. This is supported by the perception that plant and equipment was not producing products per design capacity and daily, weekly and monthly PO was not within the set target. It is further perceived that the organisational structure and size were negative, in that decisions were confined to executive management. Cross training of technical staff is ineffective and communication channels are delayed by “red tape”, which delays decisions and the flow of information.

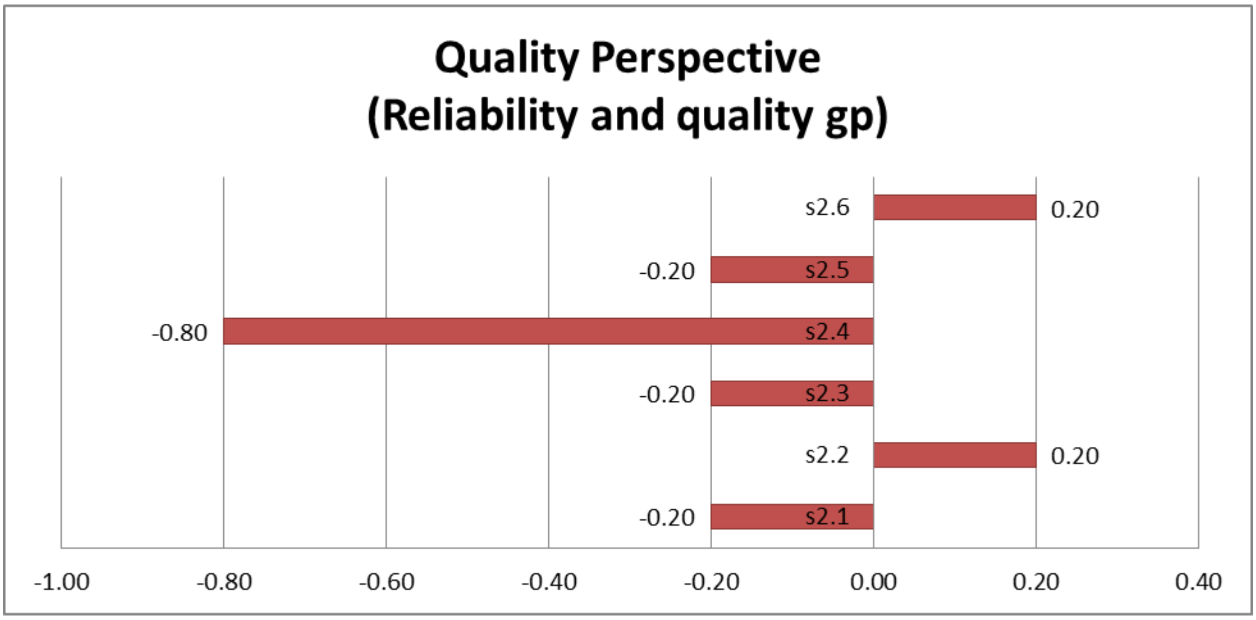

Figure 6.80 Gap analysis of quality perspective for the Production Group

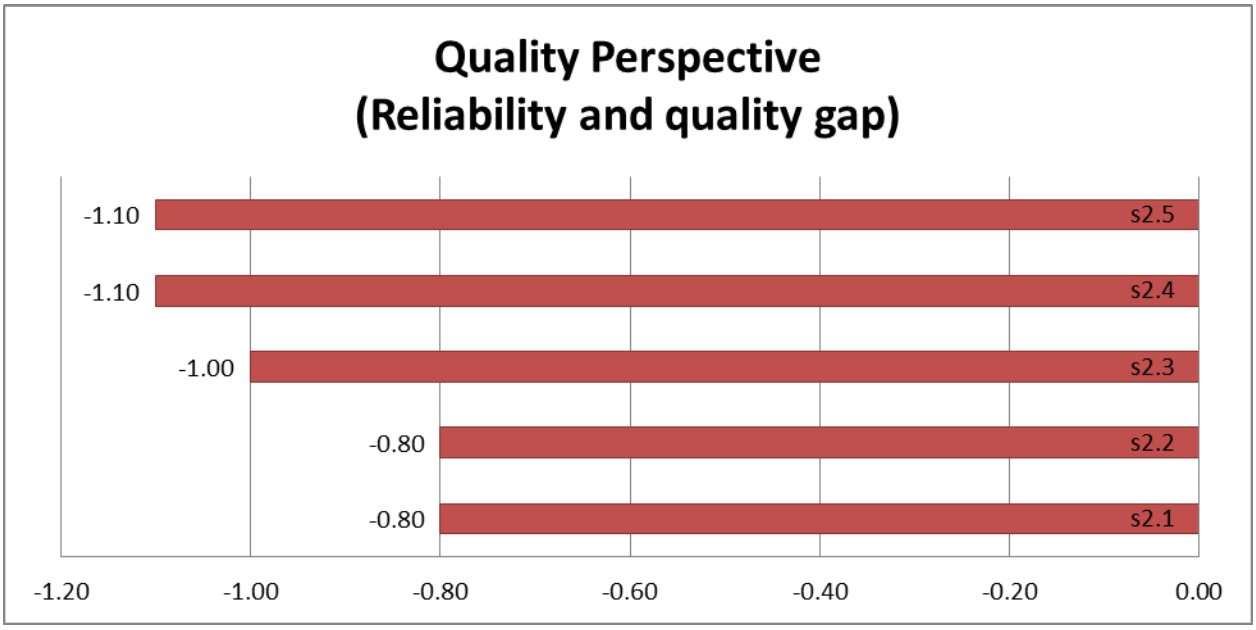

Figure 6.81 Gap analysis of quality perspective for the Maintenance Group

Figures 6.80 and 6.81 above indicate that O&U was perceived to be consistently manufacturing quality products. It is also perceived that plant and equipment breakdowns, reliability, availability, operability and efficiency do not contribute to poor product quality and production delays. Further indications are that the use of CMMS was perceived to be negative due to incomplete and unreliable maintenance-related information.

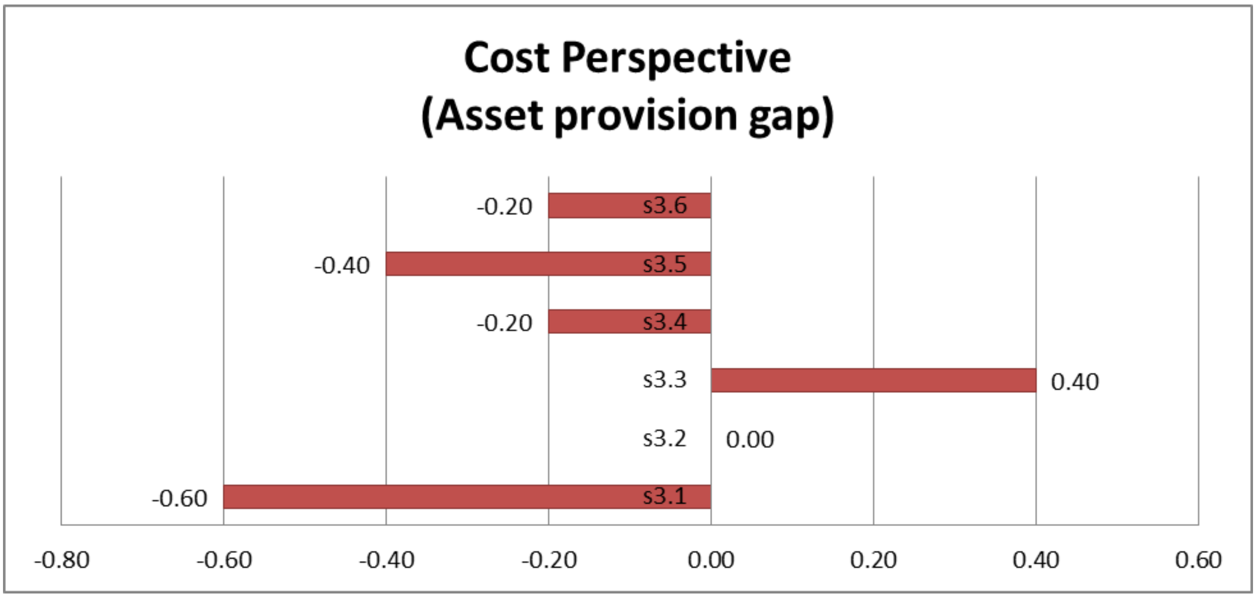

Figure 6.82 Gap analysis of cost perspective for the Production Group

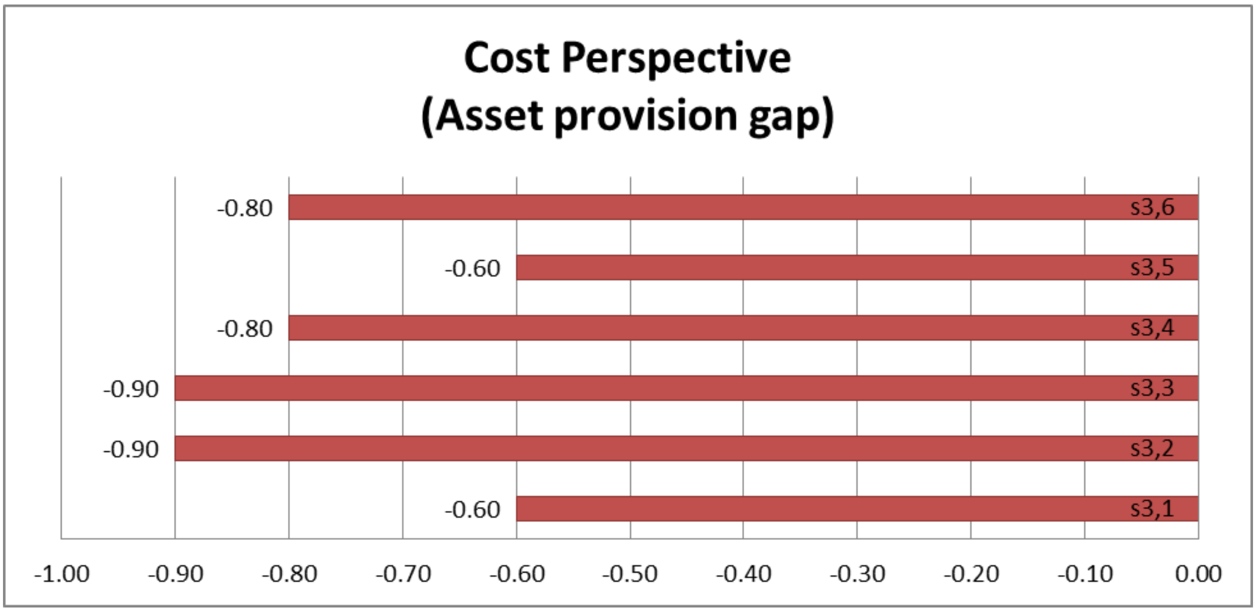

Figure 6.83 Gap analysis of cost perspective for the Maintenance Group

Figures 6.82 and 6.83 above indicate that O&U was positively perceived in that it loses income and revenue because of low production volumes. It is also perceived that work planning in terms of compiling, approving and communicating look-ahead plans was low. However, this is not supported by the perception that product prices are not reduced due to poor quality and production reworks.

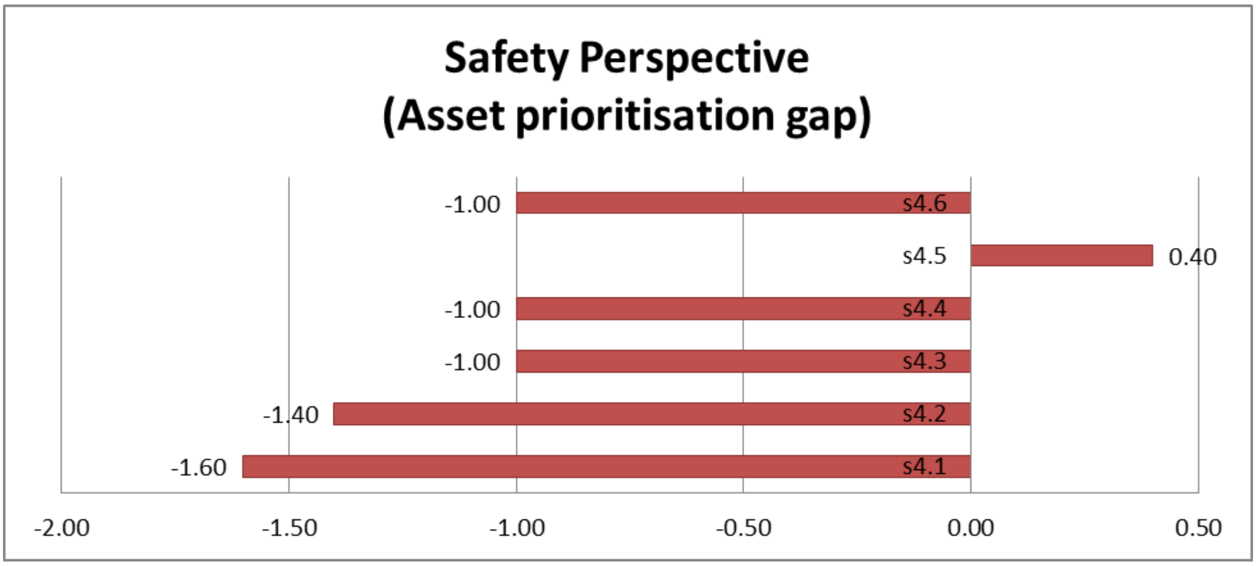

Figure 6.84 Gap analysis of safety perspective for the Production Group

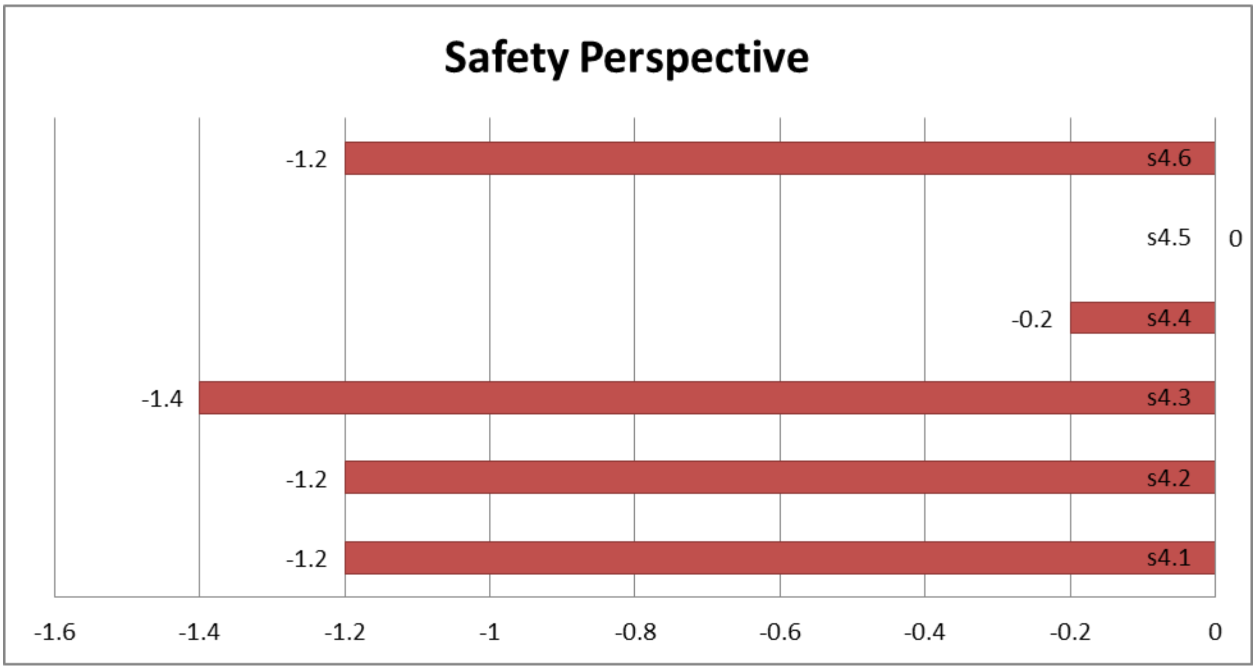

Figure 6.85 Gap analysis of safety perspective for the Maintenance Group

Figures 6.84 and 6.85 above indicate that O&U was positively perceived in that it did comply with regulatory requirements, especially lost-time injuries, which were very low. This was not supported by the level of absenteeism, injuries, overdue RBI vessels, pipelines and pressure safety valves that were perceived to be very high. The visual planning system, capacity planning system and performance management system were also perceived to be very low.

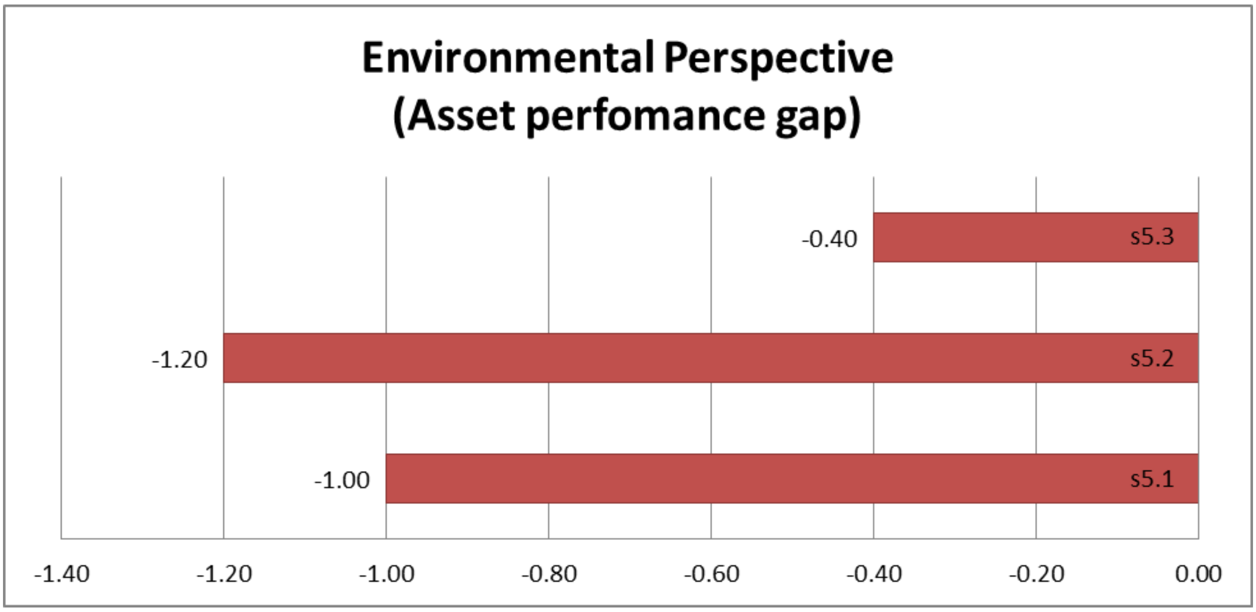

Figure 6.86 Gap analysis of environmental perspective for the Production Group

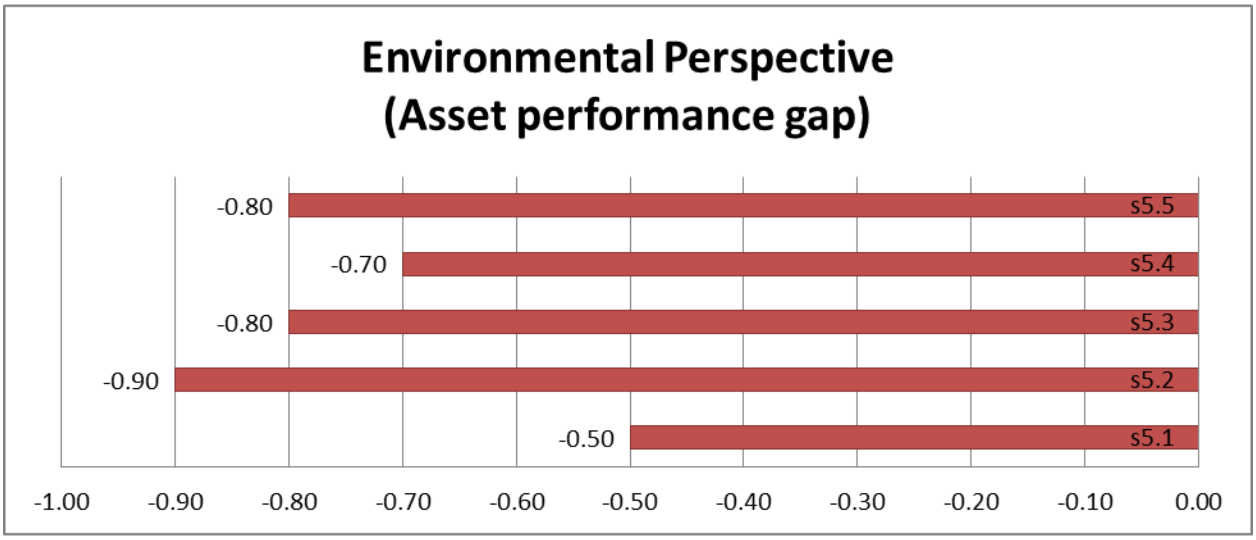

Figure 6.87 Gap analysis of environmental perspective for the Maintenance Group

Figures 6.86 and 6.87 above indicate that O&U was perceived to be negative in that minor and major product spillages and overdue priority 1 incidents were high. This is supported by the perception that material control, support, planning and availability were low.

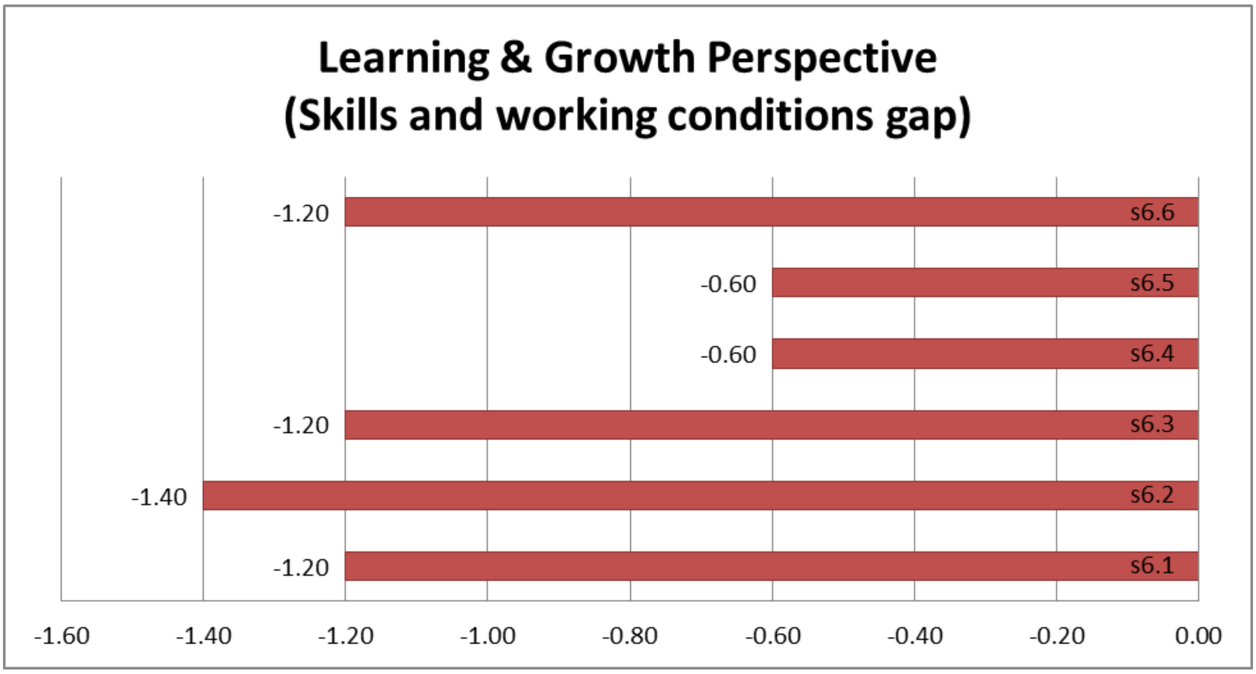

Figure 6.88 Gap analysis of learning and growth for the Production Group

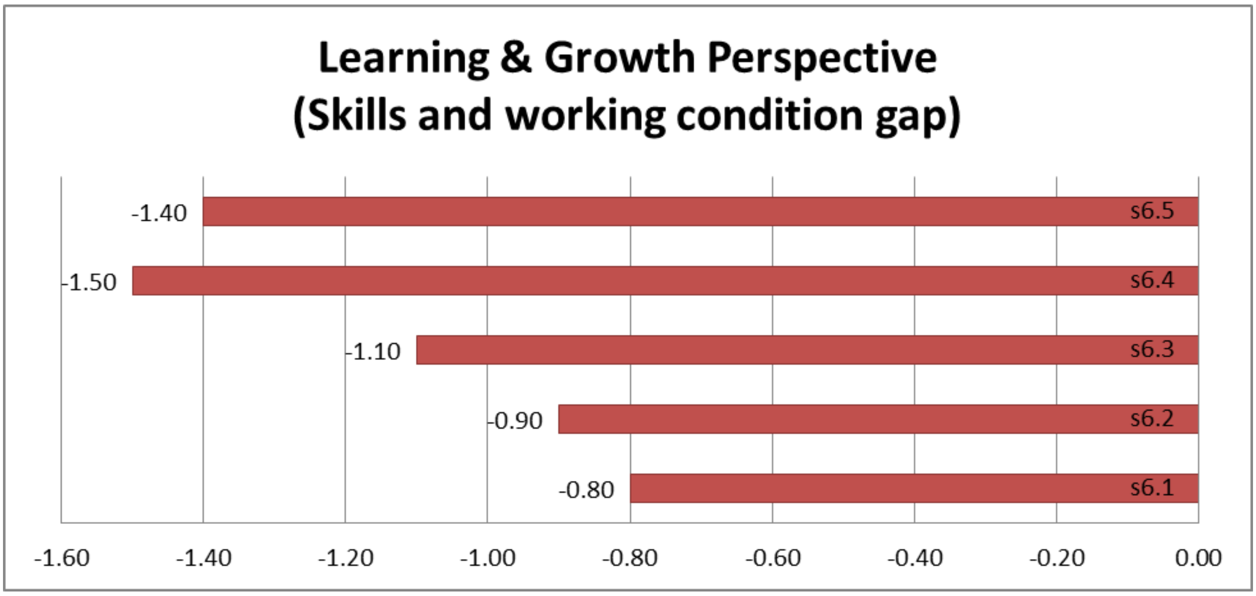

Figure 6.89 Gap analysis of learning and growth perspective for the Maintenance Group

Figures 6.88 and 6.89 above indicate that O&U was perceived to be negative or low on cross training of artisans, operators, supervisors, technicians, engineers and inspectors. Further perceptions are that the work prioritisation system was not effective, resource planning and allocation was low and scheduled jobs were not completed on time.

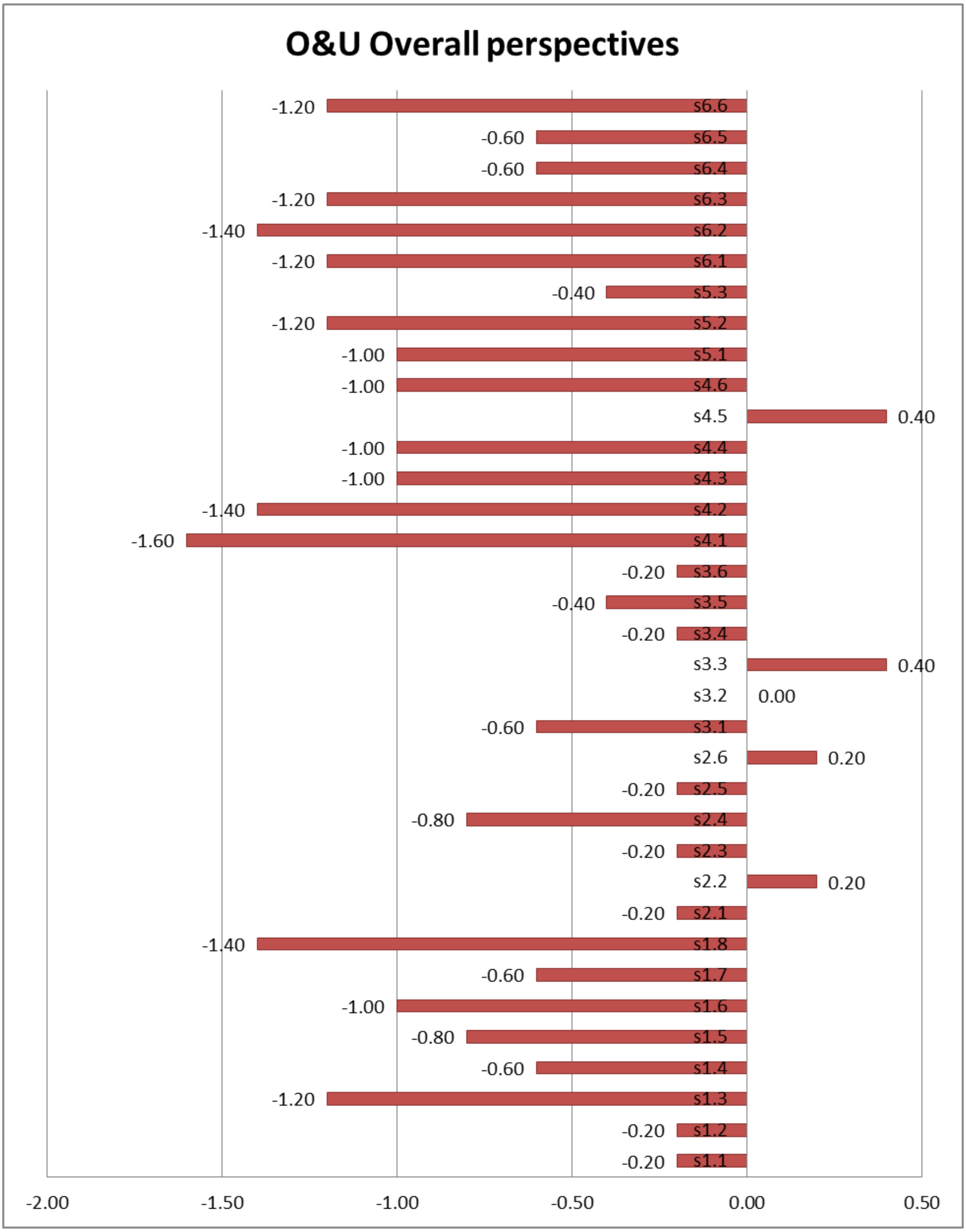

Figure 6.90 Overall dimensions gap analysis for the Production Group

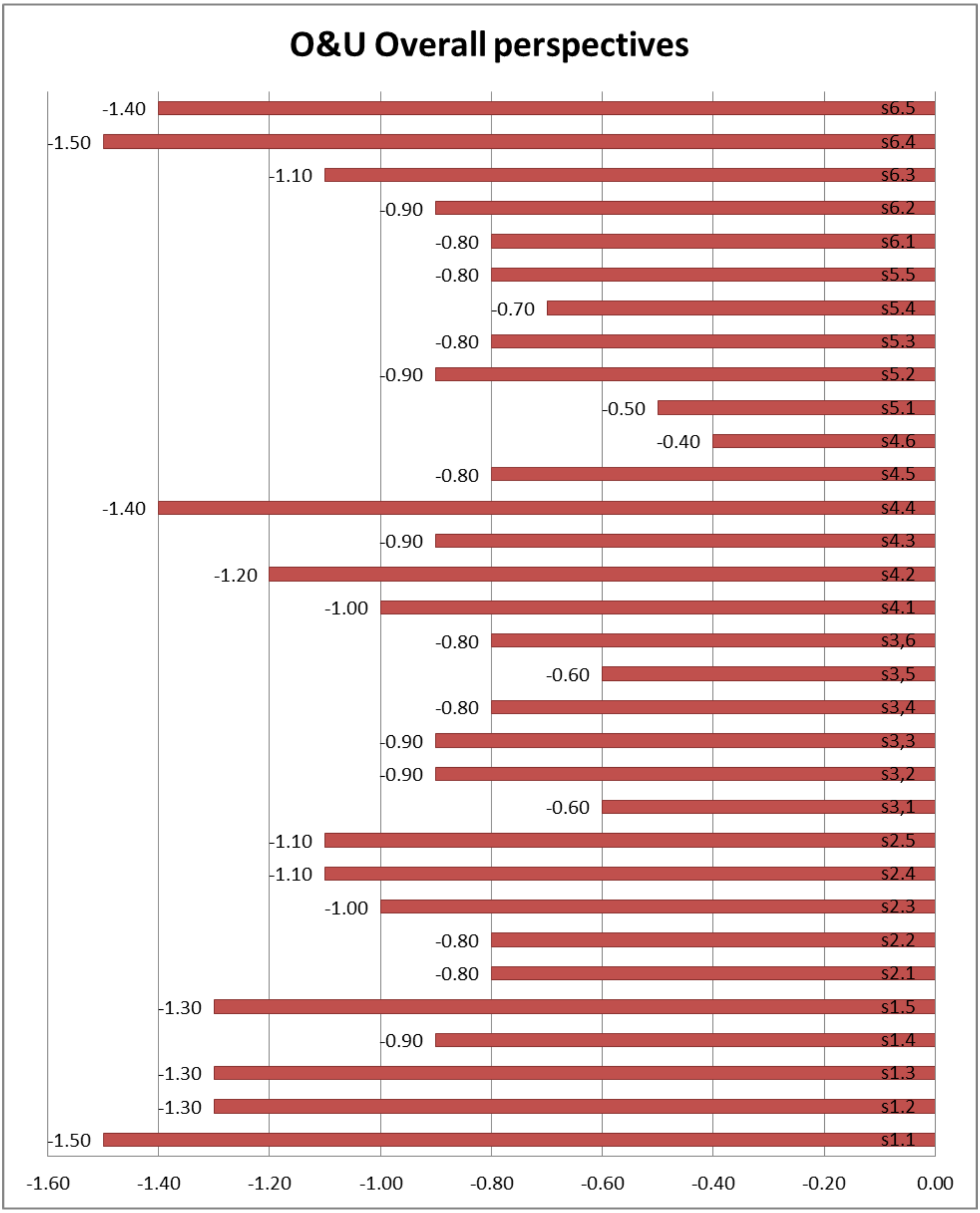

Figure 6.91 Overall dimensions gap analysis for the Maintenance Group

According to the data displayed in Figures 6.90 and 6.91 above, non-compliance with regulatory requirements in terms of overdue RBI iinspections for vessels, pipelines and pressure safety valves was perceived to be very high. This is followed by the perception that cross training of personnel was low. It is evident that on average, expectations with regard to compliance with regulatory requirements, organisational structure and size in terms of performance management, resource planning and allocation, completing work on time and cross training of personnel, exceeded perceptions.

6.4.7 Gap analysis: All areas combined (Overall)

Figures 6.92 and 6.105 below represent the MS gap analysis for the six dimensions of the PO&P for all six areas combined. Appendices E and V display the PO&P gap for all six dimensions (perspectives) for combined areas (Overall).

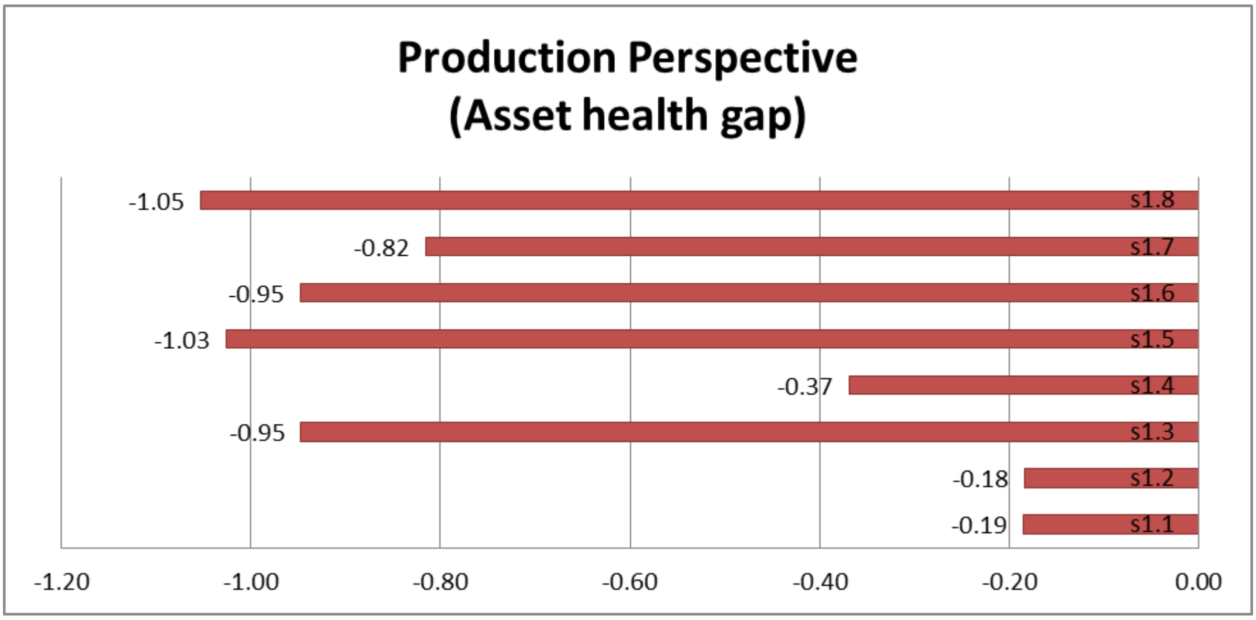

Figure 6.92 Gap analysis of production perspective for the Production Group

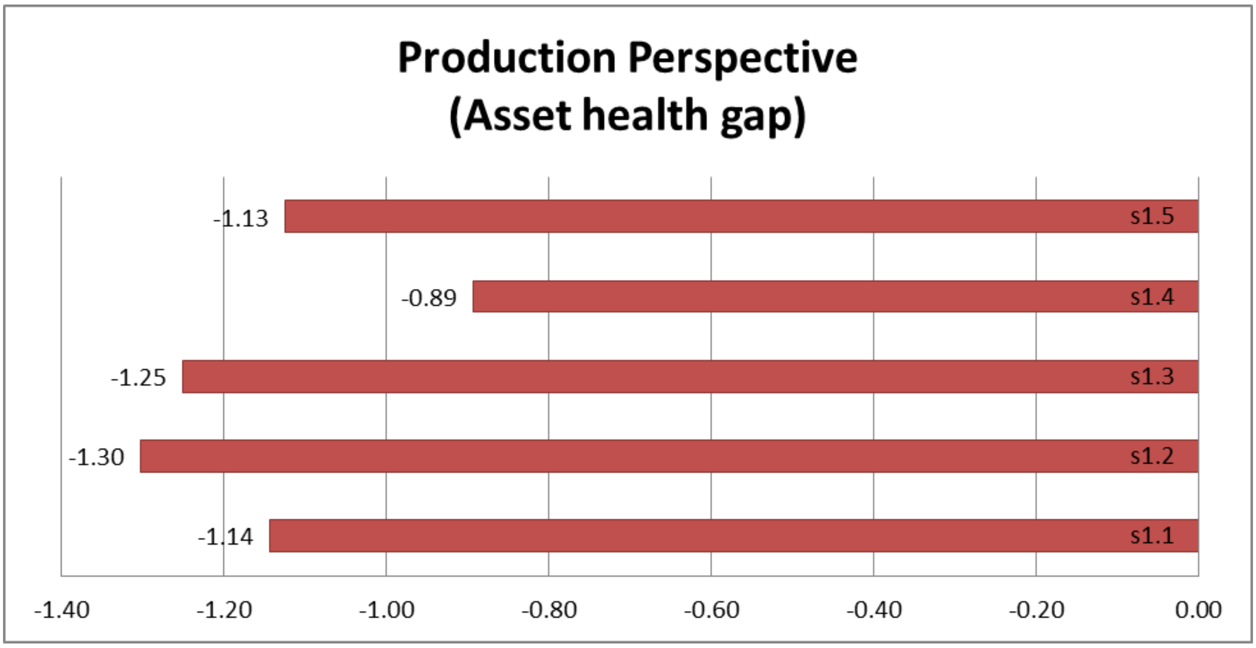

Figure 6.93 Gap analysis of production perspective for the Maintenance Group

Figures 6.92 and 6.93 above indicate that the combined areas (Overall) indicate the negative perception and image projected by the PetroSA GTL Refinery regarding production plans and schedules that were not compiled, approved and communicated to all stakeholders. This is supported by the perception that plant and equipment were always un-available, reliable, operable and efficient after executing maintenance work. It is further perceived that the organisational structure and size of the PetroSA GTL Refinery was not effective or efficient in enabling lower levels of management to make decisions, communicate important information and build cross functional relationships.

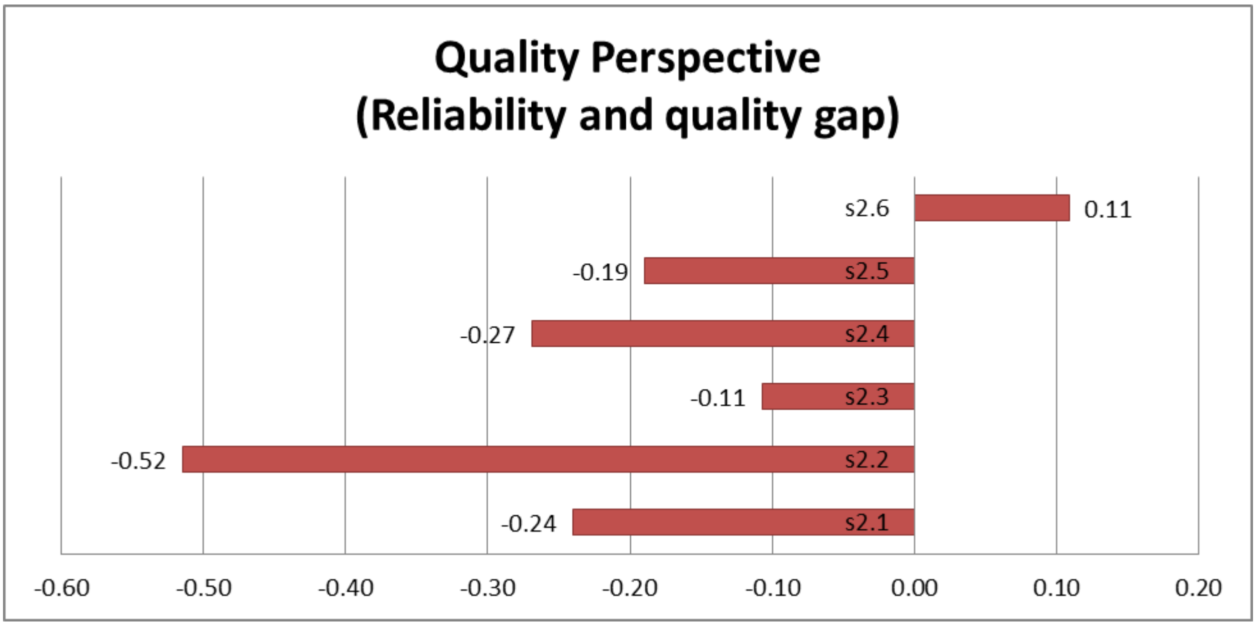

Figure 6.94 Gap analysis of quality perspective for the Production Group

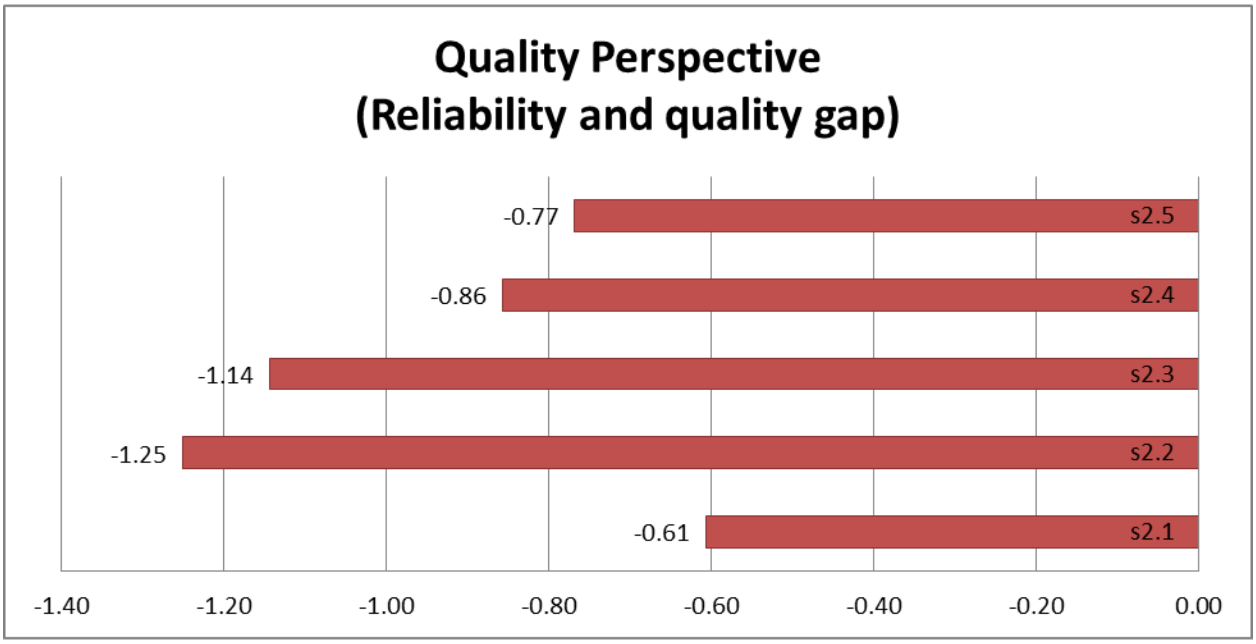

Figure 6.95 Gap analysis of quality perspective for the Maintenance Group

Figures 6.94 and 6.95 above portray a negative image projected by the PetroSA GTL Refinery with regards to inconsistently producing poor quality products that were not within the set specifications and that the maintenance and production reworks contributed to production delays. This is supported by the perception that CMMS was not effectively utilised in terms of capturing and recording reliable data and information.

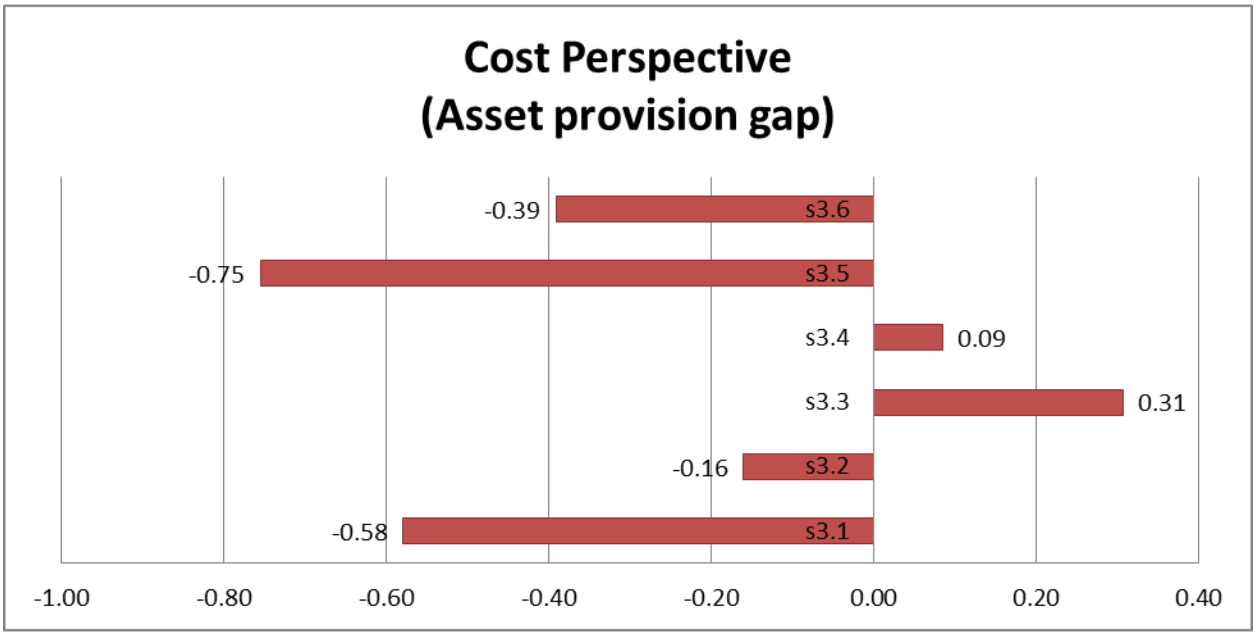

Figure 6.96 Gap analysis of cost perspective for the Production Group

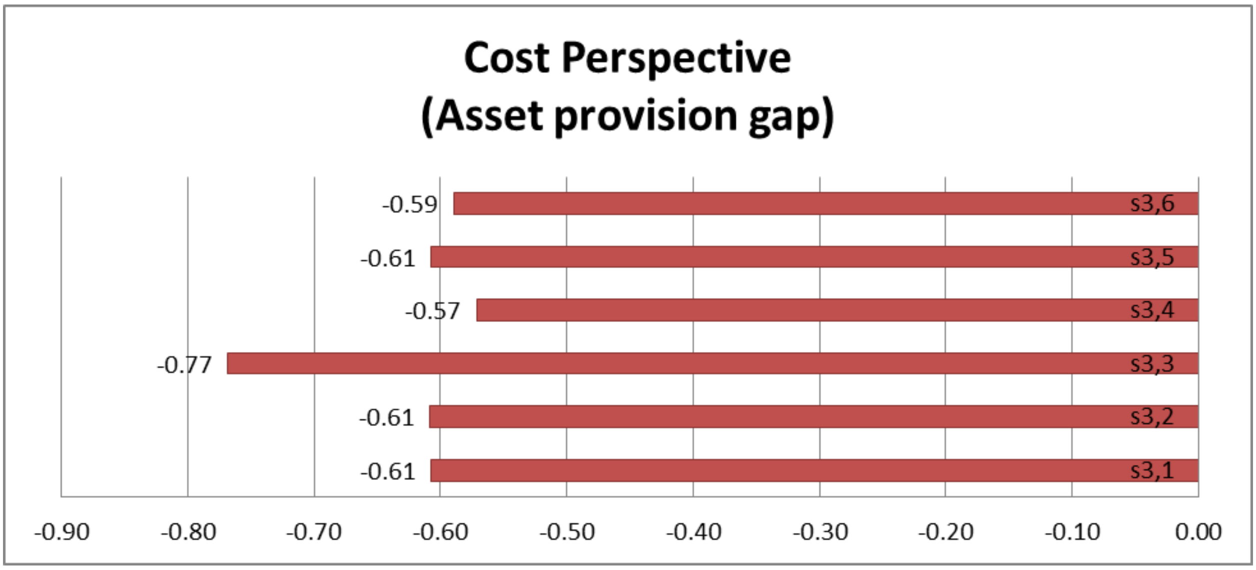

Figure 6.97 Gap analysis of cost perspective for the Maintenance Group

Figures 6.96 and 6.97 above indicate that the PetroSA GTL Refinery was losing revenue and income due to low production volumes and plant/equipment breakdowns. This is supported by the perception that weekly, monthly and yearly revenues and income were not within set targets and work planning, in terms of look-ahead plans and schedules, was rated very low.

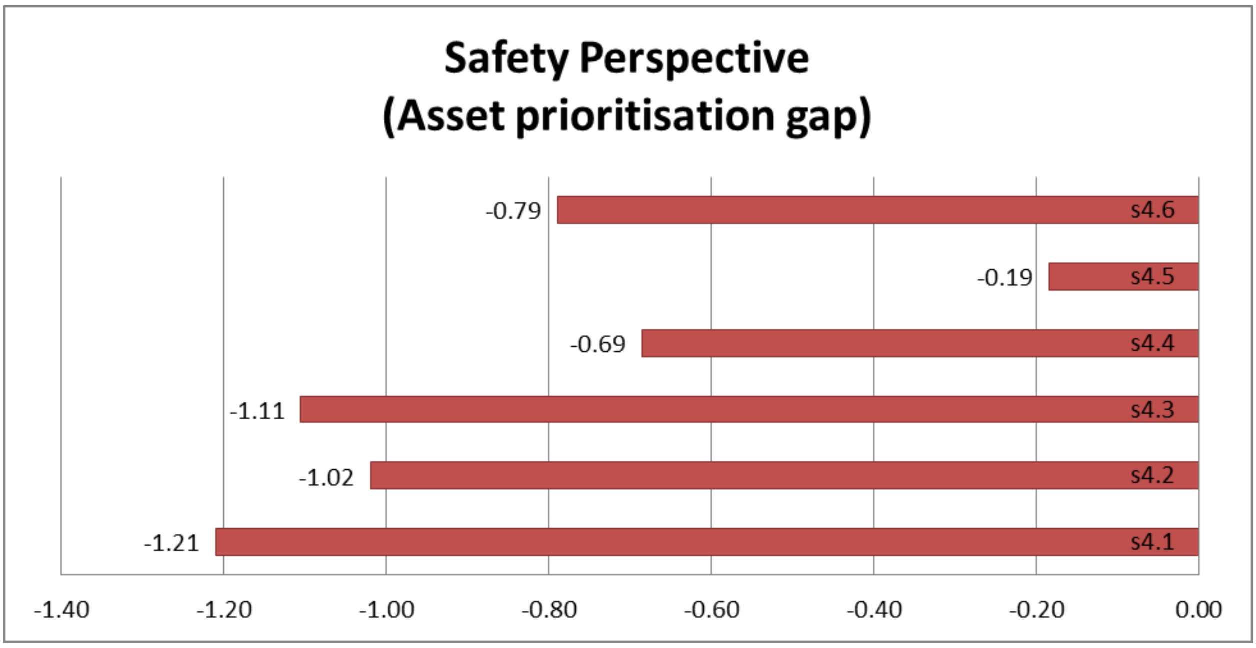

Figure 6.98 Gap analysis of safety perspective for the Production Group

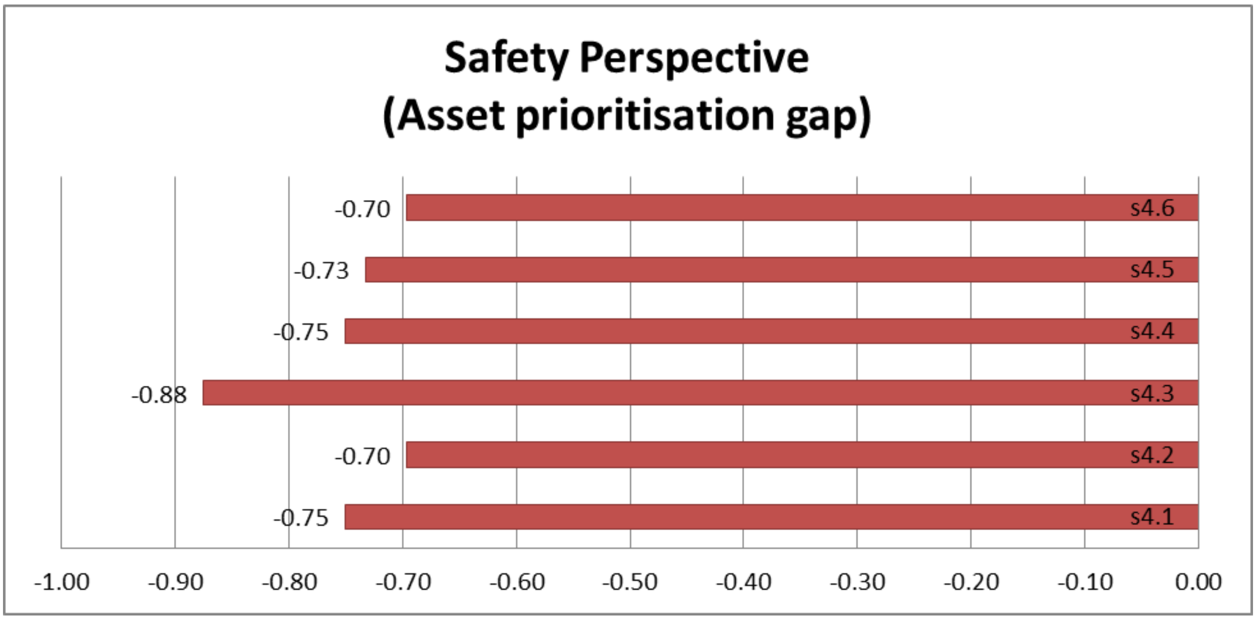

Figure 6.99 Gap analysis of safety perspective for the Maintenance Group

Figures 6.98 and 6.99 above indicate that the PetroSA GTL Refinery was not complying with set regulatory requirements in that overdue RBI inspections, injuries and absenteeism were high. This is supported by the perception that maintenance work measurement was also low, in that KPI reports, visual planning systems and capacity plans were rated very low.

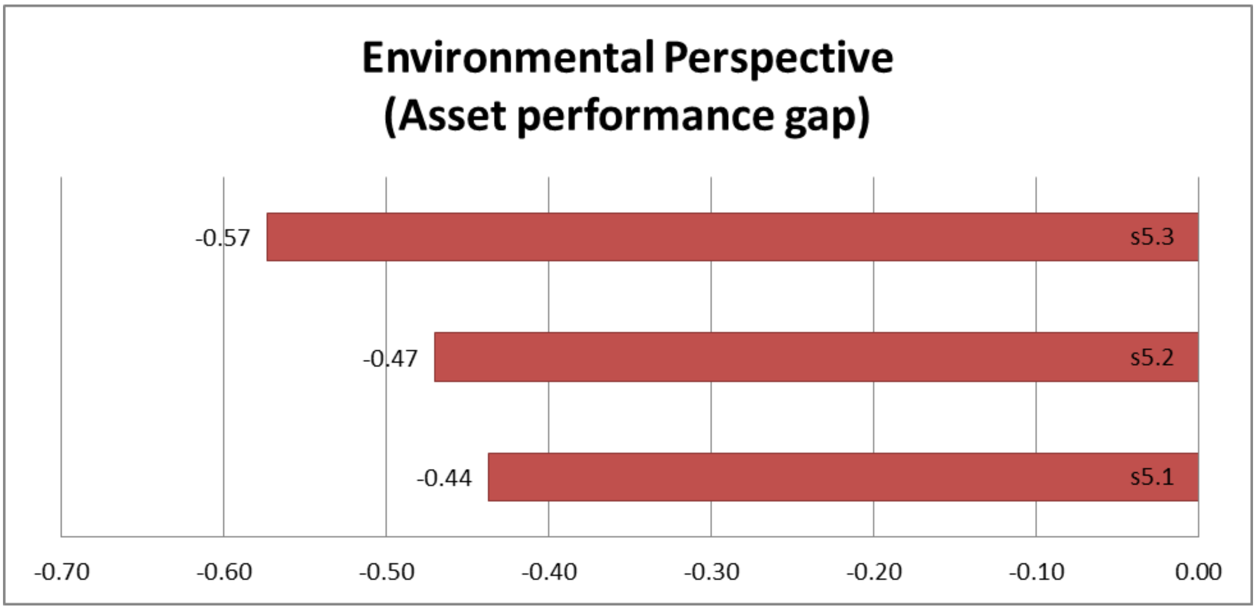

Figure 6.100 Gap analysis of environmental perspective for the Production Group

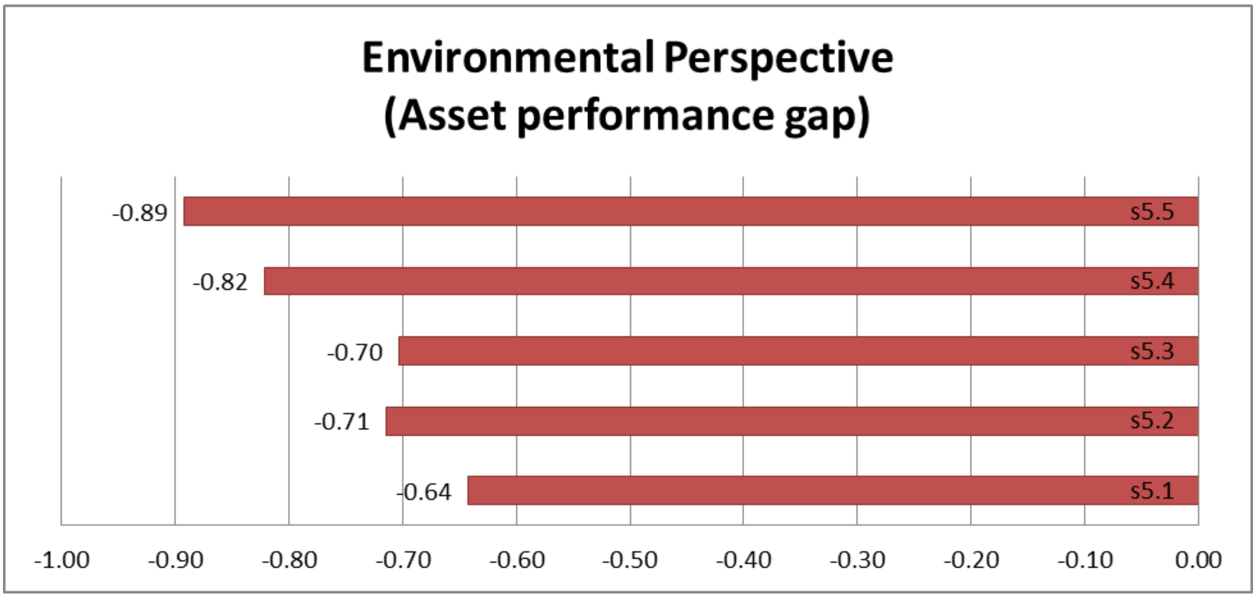

Figure 6.101 Gap analysis of environmental perspective for the Maintenance Group

Figures 6.100 and 6.101 above indicate that the PetroSA GTL Refinery was not complying with regulatory requirements in that overdue RBI inspections, overdue priority 1 incidents and the product spillages were very high. This is supported by the perception that materials control and support in terms of defining stock levels, using a part-numbering system and improving order quantity levels were low.

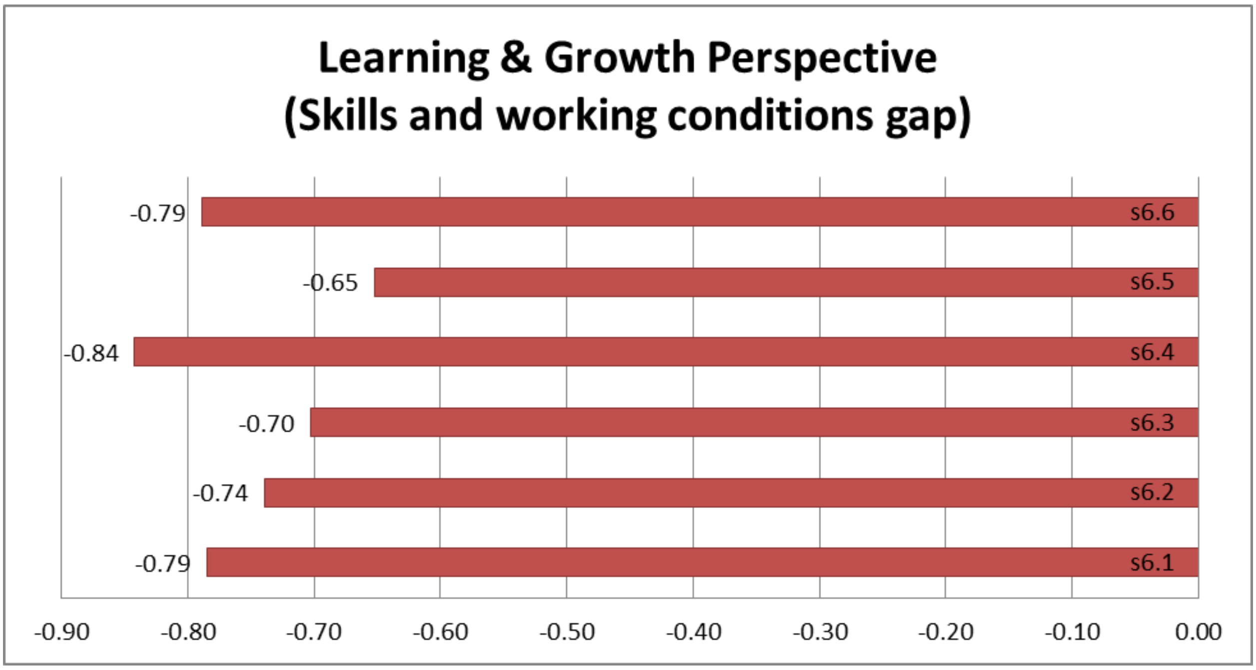

Figure 6.102 Gap analysis of learning and growth for the Production Group

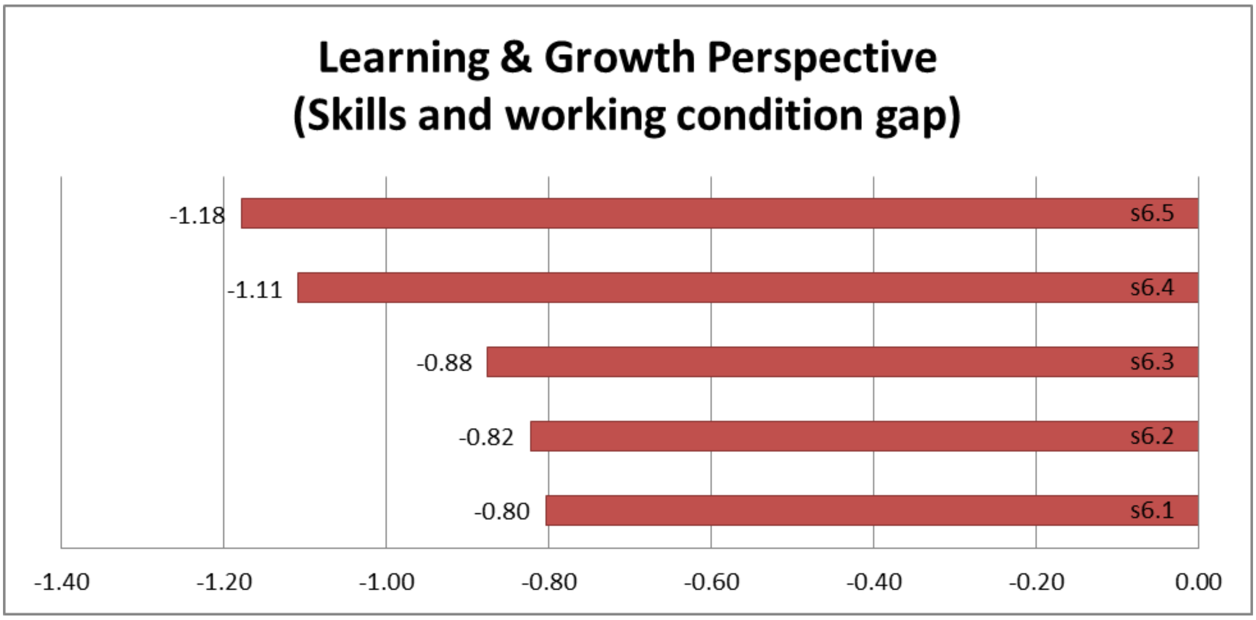

Figure 6.103 Gap analysis of learning and growth perspective for the Maintenance Group

Figures 6.102 and 6.103 above indicate the PetroSA GTL Refinery cross training programme was not effective. This is supported by the perception that maintenance scheduling and coordination in terms of resource planning and allocation, work prioritisation system and completion of planned and scheduled work, was low.

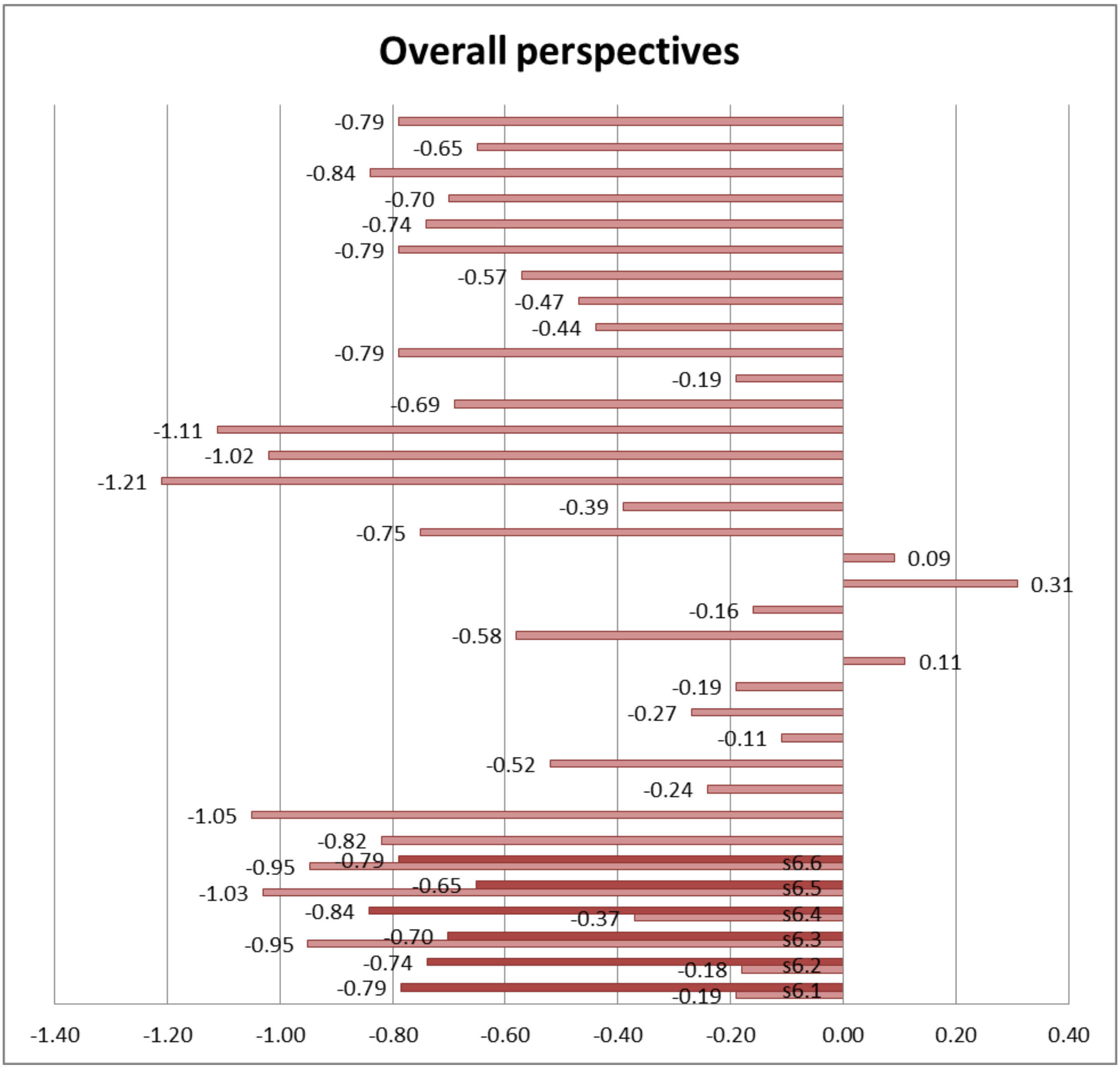

Figure 6.104 Overall dimensions gap analysis for the Production Group

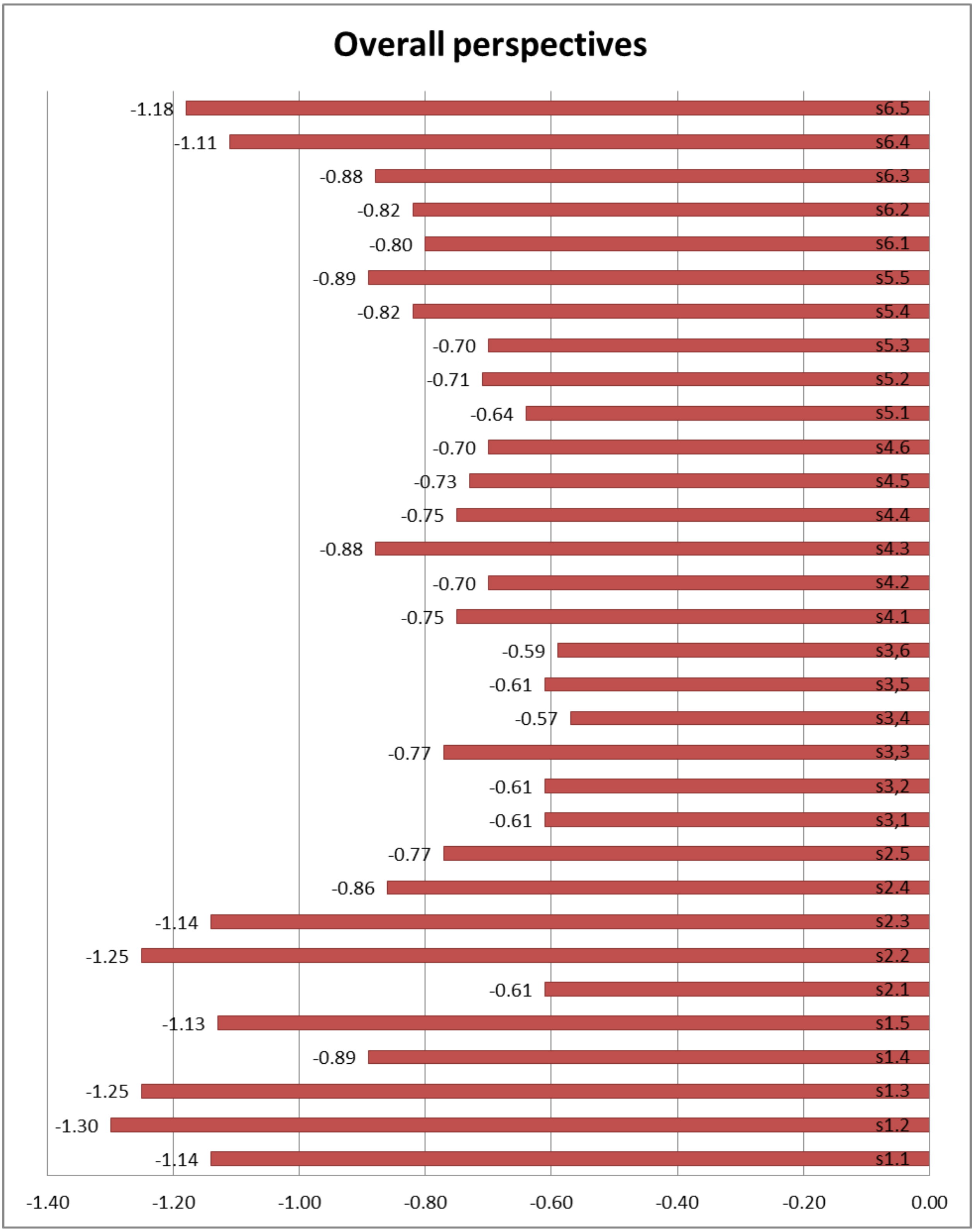

Figure 6.105 Overall dimensions gap analysis for the Maintenance Group

Figures 6.104 and 6.105 above depict the differences between perceptions and expectations for all dimensions and for all areas of the PetroSA GTL Refinery as a single group. It would appear that on average and in general, the Refinery was perceived negatively or it fared poorly in terms of:

(1) Complying with regulatory requirements, in that overdue RBI inspections for vessels, pipelines and pressure safety valves were high;

(2) Plant and equipment were not available, reliable, operable and efficient after executing maintenance work;

(3) Plant and equipment were not producing according to design capacity;

(4) Cross training of artisans, operators, supervisors, technicians, inspectors and engineers was low;

(5) Organisational structure and size was not effective and efficient, in that decisions were limited to top management only, supervisors were occupied and overloaded by administrative work and communication channels were hampered by “red tape”, thus delaying the flow of information;

(6) Weekly, monthly and annual revenue and income were not within set targets;

(7) Maintenance and production reworks contributed positively to production delays and

(8) The PetroSA GTL Refinery was losing revenue and income due to low production volumes and plant/equipment breakdowns.

Table 6.5 MS gap analysis summary – full version

AGS					
Dimension	**Population Group**	P	E	**Gap**	**Average Gap**
Production Perspective	Production Group	2.875	3.607	**-0.732**	
	Maintenance Group	2.750	4.325	**-1.575**	**-1.154**
Quality Perspective	Production Group	3.357	3.905	**-0.548**	
	Maintenance Group	3.375	4.175	**-0.800**	**-0.674**
Cost Perspective	Production Group	3.857	4.143	**-0.286**	
	Maintenance Group	3.375	3.771	**-0.396**	**-0.341**
Safety Perspective	Production Group	3.119	3.738	**-0.619**	
	Maintenance Group	2.896	3.271	**-0.375**	**-0.497**
Environmental Perspective	Production Group	3.429	3.714	**-0.285**	
	Maintenance Group	3.215	4.075	**-0.860**	**-0.573**
Learning & Growth Perspective	Production Group	2.881	3.643	**-0.762**	
	Maintenance Group	2.900	3.950	**-1.050**	**-0.906**
OVERALL GAP			**PO&PI**		**-0.691**
Dimension	**Population Group**	**P**	**E**	**Gap**	**Average Gap**
Production Perspective	Production Group	3.400	3.850	**-0.450**	
	Maintenance Group	2.850	3.750	**-0.900**	**-0.675**
Quality Perspective	Production Group	3.700	3.967	**-0.267**	
	Maintenance Group	3.125	3.875	**-0.750**	**-0.509**
Cost Perspective	Production Group	4.033	4.233	**-0.200**	
	Maintenance Group	3.438	4.375	**-0.937**	**-0.569**
Safety Perspective	Production Group	2.667	3.533	**-0.866**	
	Maintenance Group	3.979	4.188	**-0.209**	**-0.538**

Dimension	Population Group	P	E	Gap	Average Gap
Environmental Perspective	Production Group	3.533	3.733	**-0.200**	
	Maintenance Group	3.175	4.175	**-1.000**	**-0.600**
Learning & Growth Perspective	Production Group	3.767	4.067	**-0.300**	
	Maintenance Group	2.950	4.250	**-1.300**	**-0.800**
OVERALL GAP		**PO&PI**			**-0.615**
		SNT			
Dimension	**Population Group**	**P**	**E**	**Gap**	**Average Gap**
Production Perspective	Production Group	3.297	4.016	**-0.719**	
	Maintenance Group	2.355	3.867	**-1.512**	**-1.116**
Quality Perspective	Production Group	3.896	4.021	**-0.125**	
	Maintenance Group	3.178	4.556	**-1.378**	**-0.752**
Cost Perspective	Production Group	3.708	4.146	**-0.438**	
	Maintenance Group	3.870	4.648	**-0.778**	**-0.608**
Safety Perspective	Production Group	2.542	3.542	**-1.000**	
	Maintenance Group	3.593	4.537	**-0.944**	**-0.972**
Environmental Perspective	Production Group	2.778	3.458	**-0.680**	
	Maintenance Group	3.600	4.533	**-0.933**	**-0.807**
Learning & Growth Perspective	Production Group	3.111	3.854	**-0.743**	
	Maintenance Group	3.289	4.311	**-1.022**	**-0.883**
OVERALL GAP		**PO&PI**			**-0.856**
		REF			
Dimension	**Population Group**	**P**	**E**	**Gap**	**Average Gap**
Production Perspective	Production Group	3.016	3.688	**-0.672**	
	Maintenance Group	3.062	4.323	**-1.261**	**-0.967**
Quality Perspective	Production Group	4.000	4.146	**-0.146**	**-0.666**

Dimension	Population Group				
		P	E	Gap	Average Gap
	Maintenance Group	3.246	4.431	**-1.185**	
Cost Perspective	Production Group	3.833	4.021	**-0.188**	
	Maintenance Group	3.667	4.526	**-0.859**	**-0.524**
Safety Perspective	Production Group	2.833	3.792	**-0.959**	
	Maintenance Group	3.564	4.680	**-1.116**	**-1.038**
Environmental Perspective	Production Group	3.375	3.917	**-0.542**	
	Maintenance Group	3.431	4.400	**-0.969**	**-0.756**
Learning & Growth Perspective	Production Group	2.717	3.729	**-1.012**	
	Maintenance Group	3.138	4.231	**-1.093**	**-1.053**
OVERALL GAP		**PO&PI**			**-0.834**
Dimension	**Population Group**	**B&S**			
		P	**E**	**Gap**	**Average Gap**
Production Perspective	Production Group	3.500	4.200	**-0.700**	
	Maintenance Group	3.075	4.175	**-1.100**	**-0.900**
Quality Perspective	Production Group	4.200	4.200	**0.000**	
	Maintenance Group	2.950	4.200	**-1.250**	**-0.625**
Cost Perspective	Production Group	4.133	4.167	**-0.034**	
	Maintenance Group	3.438	4.375	**-0.937**	**-0.486**
Safety Perspective	Production Group	3.233	3.767	**-0.534**	
	Maintenance Group	3.354	4.354	**-1.000**	**-0.767**
Environmental Perspective	Production Group	3.533	4.133	**-0.600**	
	Maintenance Group	3.350	4.325	**-0.975**	**-0.788**
Learning & Growth Perspective	Production Group	3.233	4.067	**-0.834**	
	Maintenance Group	3.035	4.225	**-1.190**	**-1.012**
OVERALL GAP		**PO&PI**			**-0.763**
Dimension	**Population Group**	**O&U**			

Dimension	Population Group	P	E	Gap	Average Gap
		P	**E**	Gap	Average Gap
Production Perspective	Production Group	3.100	3.850	**-0.750**	
	Maintenance Group	2.920	4.180	**-1.260**	**-1.005**
Quality Perspective	Production Group	3.667	3.833	**-0.166**	
	Maintenance Group	3.460	4.420	**-0.960**	**-0.563**
Cost Perspective	Production Group	3.767	3.933	**-0.166**	
	Maintenance Group	3.650	4.417	**-0.767**	**-0.467**
Safety Perspective	Production Group	2.633	3.567	**-0.934**	
	Maintenance Group	3.350	4.300	**-0.950**	**-0.942**
Environmental Perspective	Production Group	2.800	3.667	**-0.867**	
	Maintenance Group	3.420	4.160	**-0.740**	**-0.804**
Learning & Growth Perspective	Production Group	2.500	3.533	**-1.033**	
	Maintenance Group	3.140	4.280	**-1.140**	**-1.087**
OVERALL GAP		**PO&PI**			**-0.811**

Table 6.6 MS gap analysis summary – compressed version

Dimension	Population Group	AGS				RFM				SNT			
		Perception	Expectation	Individual Gap	Average Gap	Perception	Expectation	Individual Gap	Average Gap	Perception	Expectation	Individual Gap	Average Gap
Production Perspective	PG	2.875	3.607	-0.732		3.400	3.850	-0.450		3.297	4.016	-0.719	
	MG	2.750	4.325	-1.575	-1.154	2.850	3.750	-0.900	-0.675	2.355	3.867	-1.512	-1.116
Quality Perspective	PG	3.357	3.905	-0.548		3.700	3.967	-0.267		3.896	4.021	-0.125	
	MG	3.375	4.175	-0.800	-0.674	3.125	3.875	-0.750	-0.509	3.178	4.556	-1.378	-0.752
Cost Perspective	PG	3.857	4.143	-0.286		4.033	4.233	-0.200		3.708	4.146	-0.438	
	MG	3.375	3.771	-0.396	-0.341	3.438	4.375	-0.937	-0.569	3.870	4.648	-0.778	-0.608
Safety Perspective	PG	3.119	3.738	-0.619		2.667	3.533	-0.866		2.542	3.542	-1.000	
	MG	2.896	3.271	-0.375	-0.497	3.979	4.188	-0.209	-0.538	3.593	4.537	-0.944	-0.972
Environmental Perspective	PG	3.429	3.714	-0.285		3.533	3.733	-0.200		2.778	3.458	-0.680	
	MG	3.215	4.075	-0.860	-0.573	3.175	4.175	-1.000	-0.600	3.600	4.533	-0.933	-0.807
Learning & Growth Perspective	PG	2.881	3.643	-0.762		3.767	4.067	-0.300		3.111	3.854	-0.743	
	MG	2.900	3.950	-1.050	-0.906	2.950	4.250	-1.300	-0.800	3.289	4.311	-1.022	-0.883
OVERALL GAP		PO&PI			-0.691	PO&PI			-0.615	PO&PI			-0.856

Table 6.7 MS gap analysis summary – compressed version

Dimension	Population Group	REF				B&S				O&U			
		Perception	Expectation	Individual Gap	Average Gap	Perception	Expectation	Individual Gap	Average Gap	Perception	Expectation	Individual Gap	Average Gap
Production Perspective	PG	3.016	3.688	-0.672		3.500	4.200	-0.700		3.100	3.850	-0.750	
	MG	3.062	4.323	-1.261	-0.967	3.075	4.175	-1.100	-0.900	2.920	4.180	-1.260	-1.005
Quality Perspective	PG	4.000	4.146	-0.146		4.200	4.200	0.000		3.667	3.833	-0.166	
	MG	3.246	4.431	-1.185	-0.666	2.950	4.200	-1.250	-0.625	3.460	4.420	-0.960	-0.563
Cost Perspective	PG	3.833	4.021	-0.188		4.133	4.167	-0.034		3.767	3.933	-0.166	
	MG	3.667	4.526	-0.859	-0.524	3.438	4.375	-0.937	-0.486	3.650	4.417	-0.767	-0.467
Safety Perspective	PG	2.833	3.792	-0.959		3.233	3.767	-0.534		2.633	3.567	-0.934	
	MG	3.564	4.680	-1.116	-1.038	3.354	4.354	-1.000	-0.767	3.350	4.300	-0.950	-0.942
Environmental Perspective	PG	3.375	3.917	-0.542		3.533	4.133	-0.600		2.800	3.667	-0.867	
	MG	3.431	4.400	-0.969	-0.756	3.350	4.325	-0.975	-0.788	3.420	4.160	-0.740	-0.804
Learning & Growth Perspective	PG	2.717	3.729	-1.012		3.233	4.067	-0.834		2.500	3.533	-1.033	
	MG	3.138	4.231	-1.093	-1.053	3.035	4.225	-1.190	-1.012	3.140	4.280	-1.140	-1.087
OVERALL GAP		PO&PI			-0.834	PO&PI			-0.763	PO&PI			-0.811

Tables 6.5, 6.6 and 6.7 above indicate that the smallest overall gap for PO and profitability is represented by the RFM area and it is -0.615, while the largest gap represents the SNT area at -0.856. In terms of overall individual PO&P dimensions the “production perspective” (“asset health gap”), “learning and growth perspective” (“skills and working conditions gap”) and the “safety perspective” (“asset prioritisation gap”) appear to represent the largest PO and profitability gaps.

6.5 THE MS MEANS AND STANDARD DEVIATIONS

This section will focus on the means and standard deviations of the MS survey. Appendices E and V indicate the means and standard deviations for all six areas combined into a single Production Group and Maintenance Group in the PetroSA GTL Refinery. Appendices F, G, H, I, J, K, P, Q, R, S, T and U indicate means and standard deviations per individual area.

The mean, according to Saunders *et al.* (2012:674), is an average calculated by adding up the value of each case for a variable and dividing by the total number of cases. The mean is usually accompanied by the standard deviation, which is a static measure that describes the extent of spread of data values around the mean for a variable containing numerical data. The mean is the average score for a group and is equal to the total individual scores divided by the number of scores. The standard deviation checks if the scores on a parametric test are evenly distributed and cluster closely around the mean (Welman *et al.*, 2001:206).

According to Welman *et al.* (2001:321), the empirical rule states that for any bell shaped (normal) data distribution, approximately:

1. 68% of scores fall between one standard deviation to both sides of the mean
2. 95% of scores fall between two standard deviations to both sides of the mean and
3. 99.7% of scores fall between three standard deviations to both sides of the mean.

Table 6.7 represents the mean and standard deviation per dimension overall, as well as by individual area. The data are supported by appendices E, V, F, G, H, I, J, K, P, Q, R, S, T, and U, which indicate that all values for items measured for both perceptions and expectations have roughly the same variation with all standard deviations being around 1.2. For the total group and for each area specifically, the calculated dimension scores have more or less the same variance, with standard deviations around 1.

Table 6.8 Mean and standard deviation per dimension for all areas at the PetroSA GTL Refinery

AGS						
Dimension	**Population Group**		**Perception**		**Expectation**	
		Valid N	**Mean**	**STDev**	**Mean**	**STDev**
Production Perspective	Production Group	7	2.875	0.979	3.607	0.609
	Maintenance Group	8	2.750	1.013	4.325	0.496
Quality Perspective	Production Group	7	3.357	1.285	3.905	0.644
	Maintenance Group	8	3.375	1.112	4.175	0.617

AGS						
Dimension	**Population Group**		**Perception**		**Expectation**	
		Valid N	**Mean**	**STDev**	**Mean**	**STDev**
Cost Perspective	Production Group	7	3.857	1.007	4.143	0.691
	Maintenance Group	8	3.375	0.872	3.771	0.631
Safety Perspective	Production Group	7	3.119	1.035	3.738	0.849
	Maintenance Group	8	2.896	1.013	3.271	1.028
Environmental Perspective	Production Group	7	3.429	1.130	3.714	0.776
	Maintenance Group	8	3.215	1.148	4.075	0.506
Learning & Growth Perspective	Production Group	7	2.881	0.577	3.643	1.253
	Maintenance Group	8	2.900	1.241	3.950	0.737
RFM						
Dimension	**Population Group**		**Perception**		**Expectation**	
		Valid N	**Mean**	**STDev**	**Mean**	**STDev**
Production Perspective	Production Group	5	3.400	1.178	3.850	0.335
	Maintenance Group	8	2.850	1.020	3.750	0.652
Quality Perspective	Production Group	5	3.700	0.901	3.967	0.075
	Maintenance Group	8	3.125	0.782	3.875	0.594
Cost Perspective	Production Group	5	4.033	0.731	4.233	0.298
	Maintenance Group	8	3.438	0.745	4.375	0.711
Safety Perspective	Production Group	5	2.667	1.184	3.533	0.481
	Maintenance Group	8	3.979	1.163	4.188	0.663
Environmental Perspective	Production Group	5	3.533	1.389	3.733	0.481
	Maintenance Group	8	3.175	0.850	4.175	0.622
Learning & Growth Perspective	Production Group	5	3.767	0.945	4.067	0.659
	Maintenance Group	8	2.950	0.819	4.250	0.592
SNT						
Dimension	**Population Group**		**Perception**		**Expectation**	

AGS						
Dimension	Population Group		Perception		Expectation	
		Valid N	Mean	STDev	Mean	STDev
		Valid N	Mean	STDev	Mean	STDev
Production Perspective	Production Group	8	3.297	0.852	4.016	0.569
	Maintenance Group	9	2.355	0.896	3.867	0.575
Quality Perspective	Production Group	8	3.896	0.752	4.021	0.295
	Maintenance Group	9	3.178	0.846	4.556	0.494
Cost Perspective	Production Group	8	3.708	0.841	4.146	0.445
	Maintenance Group	9	3.870	1.036	4.648	0.603
Safety Perspective	Production Group	8	2.542	1.060	3.542	0.523
	Maintenance Group	9	3.593	0.790	4.537	0.616
Environmental Perspective	Production Group	8	2.778	0.951	3.458	0.529
	Maintenance Group	9	3.600	0.771	4.533	0.637
Learning & Growth Perspective	Production Group	8	3.111	0.813	3.854	0.636
	Maintenance Group	9	3.289	0.771	4.311	0.738
REF						
Dimension	**Population Group**		**Mean**	**STDev**	**Mean**	**STDev**
		Valid N				
Production Perspective	Production Group	8	3.016	1.195	3.688	0.570
	Maintenance Group	13	3.062	0.969	4.323	0.653
Quality Perspective	Production Group	8	4.000	0.640	4.146	0.331
	Maintenance Group	13	3.246	0.813	4.431	0.571
Cost Perspective	Production Group	8	3.833	0.838	4.021	0.472
	Maintenance Group	13	3.667	0.782	4.526	0.611
Safety Perspective	Production Group	8	2.833	0.792	3.792	0.418
	Maintenance Group	13	3.564	0.610	4.680	0.584

AGS						
Dimension	**Population Group**		**Perception**		**Expectation**	
		Valid N	**Mean**	**STDev**	**Mean**	**STDev**
Environmental Perspective	Production Group	8	3.375	0.587	3.917	0.511
	Maintenance Group	13	3.431	0.752	4.400	0.674
Learning & Growth Perspective	Production Group	8	2.717	0.636	3.729	0.504
	Maintenance Group	13	3.138	0.832	4.231	0.690
B&S						
Dimension	**Population Group**		**Perception**		**Expectation**	
		Valid N	**Mean**	**STDev**	**Mean**	**STDev**
Production Perspective	Production Group	5	3.500	0.852	4.200	0.492
	Maintenance Group	8	3.075	0.939	4.175	0.577
Quality Perspective	Production Group	5	4.200	0.687	4.200	0.515
	Maintenance Group	8	2.950	1.168	4.200	0.690
Cost Perspective	Production Group	5	4.133	0.757	4.167	0.358
	Maintenance Group	8	3.438	1.158	4.375	0.748
Safety Perspective	Production Group	5	3.233	0.967	3.767	0.584
	Maintenance Group	8	3.354	0.900	4.354	0.618
Environmental Perspective	Production Group	5	3.533	0.851	4.133	0.183
	Maintenance Group	8	3.350	0.948	4.325	0.613
Learning & Growth Perspective	Production Group	5	3.233	0.858	4.067	0.611
	Maintenance Group	8	3.035	0.954	4.225	0.645
O&U						
Dimension	**Population Group**		**Perception**		**Expectation**	
		Valid N	**Mean**	**STDev**	**Mean**	**STDev**
Production Perspective	Production Group	5	3.100	0.804	3.850	0.465
	Maintenance Group	10	2.920	1.150	4.180	0.682
Quality Perspective	Production Group	5	3.667	0.938	3.833	0.659
	Maintenance Group	10	3.460	1.059	4.420	0.663

AGS						
Dimension	Population Group		Perception		Expectation	
		Valid N	Mean	STDev	Mean	STDev
Cost Perspective	Production Group	5	3.767	0.877	3.933	0.416
	Maintenance Group	10	3.650	0.983	4.417	0.679
Safety Perspective	Production Group	5	2.633	1.178	3.567	0.661
	Maintenance Group	10	3.350	1.312	4.300	0.673
Environmental Perspective	Production Group	5	2.800	1.112	3.667	0.481
	Maintenance Group	10	3.420	0.759	4.160	0.688
Learning & Growth Perspective	Production Group	5	2.500	0.716	3.533	0.406
	Maintenance Group	10	3.140	0.984	4.280	0.530
OVERALL						
			Perception		Expectation	
Dimension	**Population Group**	**Valid N**	**Mean**	**STDev**	**Mean**	**STDev**
Production Perspective	Production Group	38	3.161	1.006	3.852	0.555
	Maintenance Group	56	2.850	1.03	3.993	0.847
Quality Perspective	Production Group	38	3.820	0.930	4.022	0.502
	Maintenance Group	56	3.268	0.973	4.193	0.798
Cost Perspective	Production Group	38	3.857	0.851	4.105	0.488
	Maintenance Group	56	3.616	0.933	4.241	0.791
Safety Perspective	Production Group	38	2.829	1.057	3.661	0.604
	Maintenance Group	56	3.310	0.979	4.060	0.984
Environmental Perspective	Production Group	38	3.261	1.016	3.754	0.565
	Maintenance Group	56	3.395	0.899	4.150	0.786
Learning & Growth Perspective	Production Group	38	3.051	0.809	3.533	0.625
	Maintenance Group	56	3.071	0.967	4.029	0.823

6.6 CORRELATION ANALYSIS

As indicated in Chapter 5, section 5.4, the Pearson product moment correlation (r) was used to measure the relationship between the maintenance management system (MMS) and the PO and profitability for the six areas of the PetroSA GTL Refinery. The coefficient of determination (R^2) was also used to calculate the proportion of variance. A correlation helps to determine the strength of the linear relationship between two ranked, rated or quantifiable variables. The Pearson product moment coefficient (r) ranges from -1.00 and +1.00. Table 5.7 in Chapter 5 depicts the strength s of the positive and negative correlations.

The correlation between the MMS and PO&P is calculated by using the MS scores (means PO&PI). Appendices E and V represent the calculation of the Pearson product moment coefficient. For both population groups, the total means for perceptions and expectations were used to calculate the values of r. The MS Excel tool/spreadsheet was used to compute the values automatically as follows:

- Production Group r = 0.773
- Maintenance Group r = 0.8

The average r was calculated by getting the average for both population groups:

- r average = (r Production Group + r Maintenance Group)/2
- r average = (0.773+0.8)/2 = 0.787

The coefficient of determination was calculated by using the formula $(R)^2$

Coefficient of determination (R^2) = $(0.787)^2$= 0.619 = 61.9%.

The correlation coefficient of 0.619 represents a 61.9% relationship between MMS and PO&P. According to the data and information on Table 5.4 (Chapter 5), 0.619 represents a moderate positive linear relationship between the three constructs (MMS, PO&P). This indicates that MMS explains, influences and impacts 61.9% of the variation in PO&P of the PetroSA GTL Refinery. The production volumes (output) and profit (profitability) of the Refinery, based on world-class maintenance management systems, can be viewed with a moderate degree of confidence, since only 38.1% of the variation in PO&P is unexplained, not influenced by or impacted by maintenance management systems (MMS).

6.7 CHAPTER SUMMARY

This chapter discussed the findings of the quantitative study conducted on all six areas of the PetroSA GTL Refinery. The sections discussed are the reliability analysis of the MS assessment tool, descriptive statistics, including the designations of the respondents and the perceptions versus expectations of PO&P constructs. The chapter further introduced and provided the MS gap analysis for the six areas individually and for the Refinery as a whole. The remainder of the chapter dealt with descriptive statistics, with the emphasis on the mean and standard deviation in an effort to obtain a picture of MMS and PO&P overall values (mean) and to provide a sense of variation (standard deviation) around the mean responses. The Pearson product moment correlation coefficient (r) and the coefficient of determination (R^2) were also introduced and utilised to determine the strength of the linear relationship between the three constructs (MMS, PO&P). Chapter 6 concluded with the correlation analysis.

It is evident from the empirical findings in this chapter that there are conclusive variations or differences in levels of MMS and PO&P practiced and provided in each of the six areas of the PetroSA GTL Refinery. In order to improve PO&P, area managers should start by addressing the safety perspective in terms of complying with regulatory requirements. In addition, they should pay more attention to production and quality perspectives in terms of cross training technical personnel, improving plant and equipment availability, reliability, operability and efficiency after executing all maintenance work.

Chapter 7 draws conclusions for this study and makes recommendations for possible future research.

Chapter 7: CONCLUSION

7.1 INTRODUCTION

This chapter introduces and addresses an overview of the research study and provides the schematic diagram of the research study as it was conducted (section 7.2, Figure 7.2). In section 7.3 of this chapter, the main findings of the research study are introduced and unpacked. Factors such as the achievement of the primary and secondary objectives are discussed.

Section 7.4 of this chapter addresses the validity and reliability of the research study. The chapter further elaborates on the limitations and delimitations of the research study (section 7.5). The research conclusions form part of this chapter and are depicted in section 7.6. The chapter concludes with the recommendations of the research study highlighted in section 7.7.

The main sections of this chapter are depicted in Figure 7.1 below

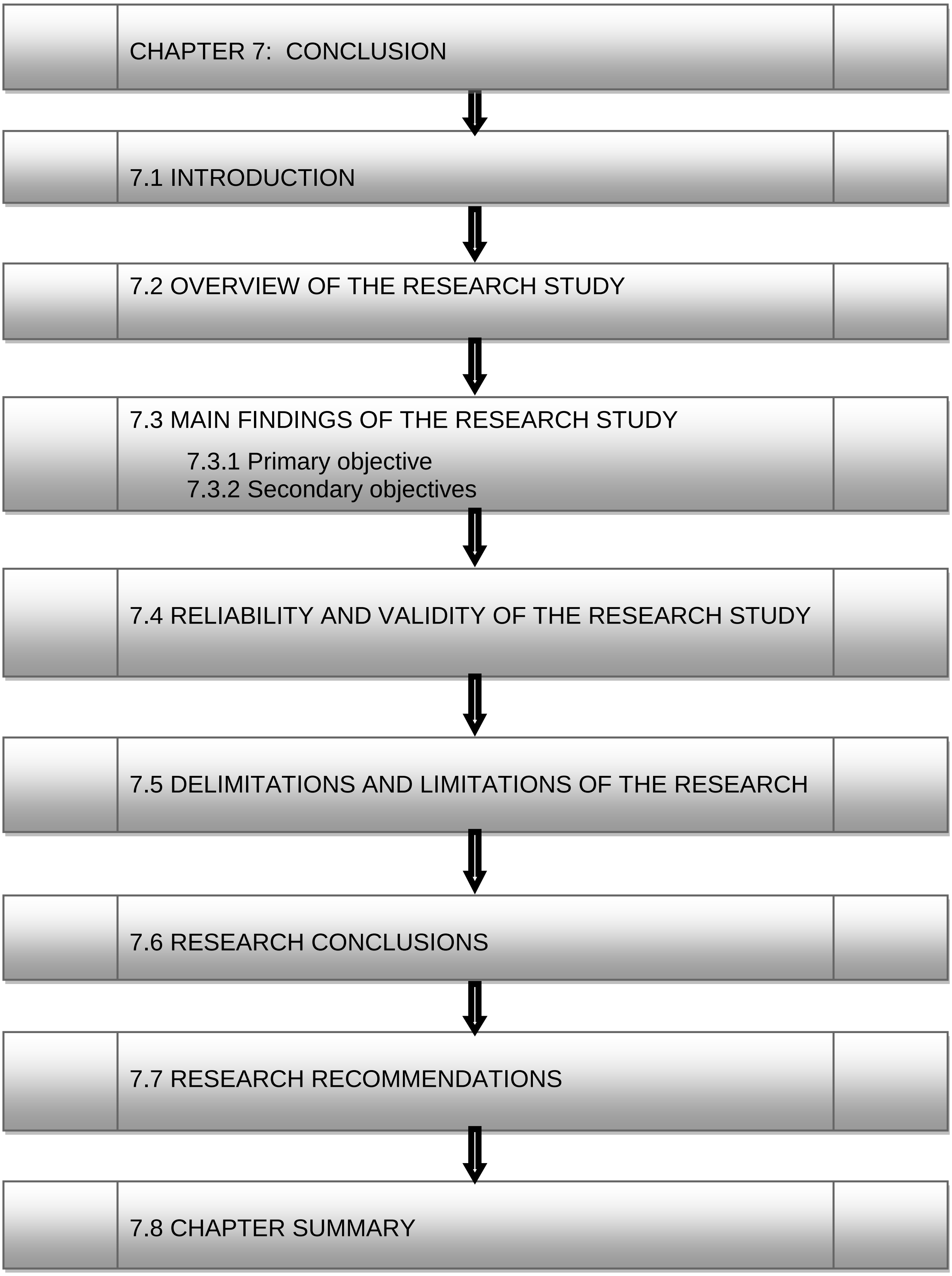

Figure 7.1 Layout of Chapter 7

7.2 OVERVIEW OF THE RESEARCH

In the abundance of literature on maintenance management systems (MMS), production output and profitability (PO&P), no academic work was found that focused on the relationship between MMS and PO&P at the PetroSA GTL Refinery (or any refinery). This study comprises seven chapters, investigating the impact of MMS on PO&P at the PetroSA GTL Refinery, that is, the impact of the MMS (the independent variable) on PO&P (the dependent variable).

Chapter 1 provided a brief overview of the background of the study and the problem statement (hypothesis) and further introduced and addressed the primary and secondary research objectives, the research method and definitions and abbreviations.

Chapters 2, 3 and 4 formed part of the literature review. Chapter 2 explored asset management and maintenance. The status of asset management and maintenance in developed and developing countries is considered and compared. The chapter also introduced and investigated the asset management framework, asset management challenges, maintenance strategies, maintenance cycle, maintenance challenges and maintenance best practices.

Chapter 3 focused on MMSs. The definitions and insight were provided in terms of the different types of MMS. The chapter further provided an in-depth overview of the adapted maintenance scorecard (MS) assessment tool that was used to conduct this study.

Chapter 4 provided a detailed review of the existing literature on profit and profitability. The chapter reviewed different theories of profit, the objectives of profit and the value of an organisation. The chapter concluded with a review of existing literature on the function of profit.

In Chapter 5, the research design and methodology employed are explained. The investigation revolved around the research strategy that was adopted, the data collection method, data analysis, research quality, delimitations and research ethics.

Chapter 6 presented the data and findings of the surveys conducted in the six areas of the PetroSA GTL Refinery. The data included descriptive statistics, such as an analysis of PO&P perceptions and expectations, the PO&P gap analysis and means and standard deviations. This chapter summarised the findings, reliability and validity of the research and summarised limitations and delimitations. The chapter concluded with conclusions and recommendations for possible further research. The summary of findings included an analysis of the purpose of the study, a description of the methodology used, how the primary and secondary objectives were achieved and an explanation of the results of the data analysis.

Furthermore, Chapter 6 confirmed and focused on the reliability and validity of the research and the delimitations and limitations of the study. The chapter concluded by drawing conclusions and making recommendations for possible further research.

Figure 7.2 depicts a schematic diagram of the research conducted, Chapters 1 to 7.

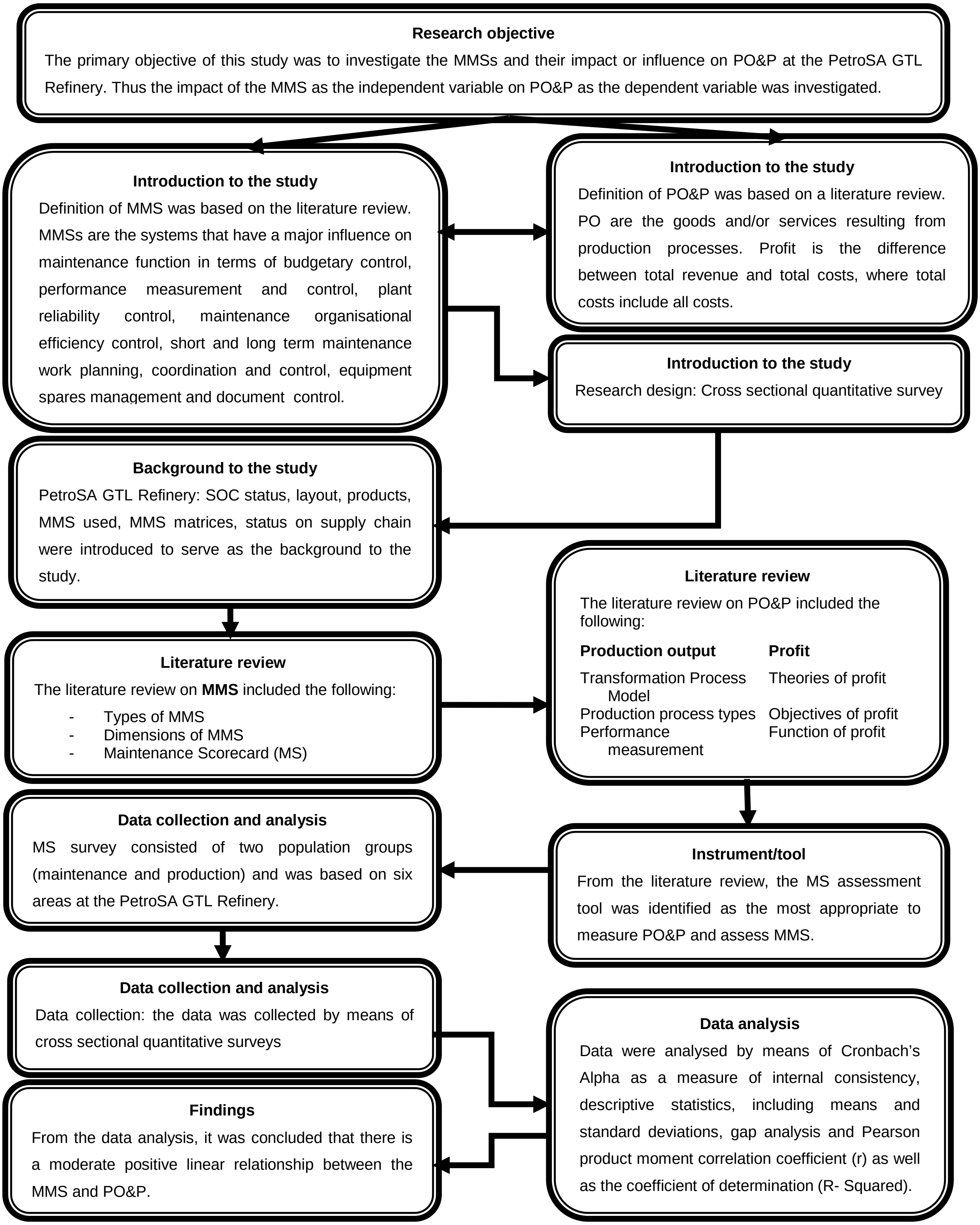

Figure 7.2: A schematic diagram representation of this study

7.3 MAIN FINDINGS OF THE RESEARCH

The primary objective of this study was to investigate the impact of the MMS on PO&P at the PetroSA GTL Refinery; hence, the impact on the MMS as the independent variable and on PO&P as the dependant variables was studied, examined and investigated.

The positivism paradigm and a deductive process were employed and applied. The data collection strategy used was based on a cross sectional quantitative survey to study the MMS and PO&P. The PO&P research data were gathered and collected by means of the MS assessment tool for both the maintenance and production population groups. The research population (the actual number of respondents) was divided into two groups as indicated above. The maintenance group consisted of 56 maintenance employees categorised by trades (artisans, technicians, supervisors, engineers, managers and planners). The Production Group consisted of 38 operations employees categorised by designations (process controllers/operators, supervisors, specialists, managers, superintendents and engineers).

The survey used designations and/or trades as the respondents' demographics. The demographic data were not discussed in detail because they did not form part of the research objectives of this study. Two types of MS questionnaire were used to collect data, one for the maintenance group and the other for the Production Group. The Microsoft Excel spread sheet tool was used to compute all statistical procedures. Data were analysed by means of Cronbach's Alpha as a measure of internal consistency. The descriptive statistics, including means and standard deviations, gap analysis, the Pearson product moment correlation coefficient (r) and the coefficient of determination (R^2) were used to analyse data. Demographic data provided additional information on and insight into the participants in the survey.

The quantitative results of the survey were presented, explained and analysed in Chapter 6. The following section addresses the primary and secondary objectives.

7.3.1 Primary objective

The primary objective of this study was to investigate the MMSs and their impact or influence on PO&P at the PetroSA GTL Refinery. A comprehensive literature study on asset management and maintenance (Chapter 2), MMSs (Chapter 3) and PO&P (Chapter 4) was conducted and perspectives on these constructs and the impact of MMS on PO&P were investigated and analysed. The empirical findings in Chapter 6, section 6.6, indicated the existence of a moderate positive linear relationship between the three constructs (MSS and PO&P). Based on these results, it was confirmed that there is indeed a moderate positive linear relationship between MMSs and PO&P at the PetroSA GTL Refinery. Tables 6.5 and 6.6 and Figures 6.5 and 6.7 in Chapter 6 depict these findings visually.

The secondary objectives stated in Chapter 1, section 1.9.2, contributed to the achievement of the primary objective. The next section will focus on how the secondary objectives were achieved.

7.3.2 Secondary objectives

In order to achieve the primary objectives, the following secondary objectives were set and pursued:

(1) To identify and document the MMS at the PetroSA GTL Refinery.

In order to achieve this objective, the literature review was done and five key types of MMSs were identified and investigated in Chapter 3, section 3.3. Section 3.3.5 identified risk based inspection as one of the key MMSs; this MMS type is used by the PetroSA GTL Refinery, as indicated in Chapter 1, section 2.2.

(2) To identify the barriers and/or the causes which prevent the achievement of planned/scheduled PO at the PetroSA GTL Refinery.

This objective focused on the analysis of the perceptions and expectations of PO&P and was addressed in Chapter 6, section 6.4, (MS gap analysis). Figures 6.8 and 6.9 in section 6.4.1 indicated that PO was not within the planned/scheduled PO in Air and Gas Separation, due to plant and equipment breakdowns. Figures 6.22 and 6.23 in section 6.4.2 indicated that PO was not within scheduled/planned targets in Reforming due to plant and equipment breakdowns. Figures 6.39 and 6.40 in section 6.4.3 indicated that production volumes were reduced in Synthol due to plant and equipment breakdowns. This also influenced weekly, monthly and yearly PO, which was indicated as not being within scheduled/planned targets. Further evidence was indicated by Figures 6.52 and 6.53 in section 6.4.4, in that daily, weekly and monthly PO was not within the scheduled/planned targets due to plant and equipment that was not available, reliable, operable and efficient after executing maintenance work.

(3) To analyse problems in the MMS that may lead to interrupted PO at the PetroSA GTL Refinery.

This objective focused on the analysis of the perceptions and expectations of the PO&P. This was addressed in Chapter 6, Figures 6.94 and 6.95, section 6.4.7, which indicated that on average the PetroSA GTL Refinery plant and equipment was not available, reliable, operable and efficient after executing maintenance work.

(4) To analyse the effect of interrupted PO on the maximisation of profit for the PetroSA GTL Refinery.

This objective focused on the analysis of the perceptions and expectations of the PO&P. The MS assessment tool was identified as the most appropriate means of assessing PO&P. This objective was addressed in Chapter 6, section 6.4.7, Figures 6.98 and 6.99, which indicated that the PetroSA GTL Refinery was losing revenue and income because of low production volumes. The analysis also depicted that due to this, weekly, monthly and yearly revenues and income were not within set targets.

(5) To evaluate how the PetroSA GTL Refinery can improve its MMS to achieve planned/scheduled PO and profit maximisation.

This objective also focused on the analysis of the perceptions and expectations of the PO&P and was addressed in Chapter 6, section 6.4.7, which indicated that cross training and development of artisans, engineers, technicians, operators, supervisors, specialists, superintendents and managers was a serious concern (very low). The focus in this case as in this analysis, is to improve cross training of these resources, which will implement and improve utilisation of MMS.

(6) To recommend interventions to improve the MMS to achieve planned/scheduled PO and profit maximisation for the PetroSA GTL Refinery (a state-owned company).

The aim of this objective was to recommend interventions to improve MMS at the PetroSA GTL Refinery. Based on the results obtained in Chapter 6, the following guidelines are suggested:

a) Chapter 6, section 6.4.7 indicated that production perspective (asset health), learning and growth perspective (skills and working conditions) and safety perspective (asset prioritisation) represented the largest PO&P gap. Hence, the first step for the PetroSA GTL Refinery would be to improve MMS by addressing these three dimensions.

b) Sections 7.2.1 and 7.2.2 indicated the primary and secondary objectives of the study as stated in Chapter 1. Sections 1.91 and 1.92 were addressed.

The next section focuses on the reliability and validity of this study.

7.4 RELIABILITY AND VALIDITY OF THE RESEARCH RESULTS

As stated in Chapter 5, section 5.3.1.2, according to Cameron and Price (2009:XXVII), reliability refers to the statistical likelihood that repeating the data collection exercise will produce similar results. Furthermore, in Chapter 5, Table 5.3, it was indicated that:

(1) The researcher-participant interaction played a positive role in ensuring that quality time was allocated and afforded to completing and submitting questionnaires ("participation error");

(2) The researcher-participant interaction was a one-on-one relationship ("participation bias");

(3) The researcher planned and scheduled milestones to ensure that this study was done and completed in a more realistic time in an attempt to deal with "research error" threat to reliability and

(4) The researcher used data and information provided by respondents in questionnaires. Nothing was added or removed ("researcher bias").

The above indicates that the MS questionnaires demonstrated high reliability. In Chapter 5, section 5.5, it was indicated that Cronbach's Alpha was employed to compute the average of all possible split half reliabilities for a multiple item scale to measure the quality of internal consistency. According to Hair *et al.* (2011), Cronbach's Alpha measures internal consistency reliability and a Cronbach's Alpha of 1.00 indicates complete consistency in all items, yields and corresponding values. Tables 6.1, 6.2 and 6.3 in Chapter 6, section 6.2, confirm the internal consistency of both the perception and expectation dimensions of the MS assessment tool. The Cronbach's Alpha for perception dimensions varied between 0.63 and 0.87, while the expectation dimensions varied between 0.68 and 0.92. On the strength of the rule of thumb suggested by Hair *et al.* (2011:235) in Chapter 5, section 5.5, Table 5.9, the reliability of the MS assessment tool can be described as varying between moderate and excellent. Both MS questionnaires for the Maintenance and Production Groups have proven to be reliable and valid assessment tools.

As stated in Chapter 5, section 5.3.1.3, according to Cameron and Price (2009:216), validity refers to the extent to which the indicator measures what it purports to measure. In support of this, Zikmund *et al* (2013:303) confirm that validity is the accuracy of a measure or the extent to which a score truthfully represents a concept. To address the question of the validity of the research results, Page *et al* (2003:86) state that validity is usually discussed in terms of internal and external validity. The authors elaborate that internal validity refers to the extent to which the measure can be said to reflect changes in responses caused by manipulation (changing levels, values and hence influence) of the independent variable(s).

The MS questionnaires were completed and sent back to the researcher and are available to check and confirm that the rating results were not manipulated.

In closing, the authors state that the external validity refers to the assumption of generalisability, the extent to which the results are relevant to individuals and settings beyond the study conditions. The MS questionnaires were designed to address or investigate the relationship of the three constructs, namely the maintenance management system (MMS) and production output and profitability (PO&P). Based on the total number of respondents versus the total number of available employees at the PetroSA GTL Refinery, the question of generalisation or generalisability of research results cannot be ruled out. To demonstrate validity of the research results the following three aspects of validity were investigated and confirmed:

(1) Face validity: according to Page *et al* (2003:86), face validity is established by determining on face value whether the items are logically and conceptually accurate. The MS questionnaires were designed and Likert scales ranging from 1 to 5 were used. The data collected was based on these ratings and on face value data collected represented logical and conceptual accuracy as per appendices B to V.

(2) Content validity: according to Page *et al* (2003:86), content validity refers to where the items are shown to represent fully the area under study with no omission. This was addressed and is depicted in appendices E to V. The data was collected in all six areas of the PetroSA GTL Refinery and covered the six dimensions namely production, quality, cost, safety, environmental and learning and growth perspectives.

(3) Construct validity: according to Page *et al* (2003:86), construct validity refers to how well the variables were selected and defined with regard to the construct being measured. The maintenance scorecard (MS) assessment tool was used to assess and measure the relationship between the three constructs (MMS and PO&P). The MS assessment tool identifies six perspectives as listed above that are designed to address the validity of the independent construct (MMS).

7.5 DELIMITATIONS AND LIMITATIONS OF THE RESEARCH

It is necessary to highlight the delimitations of this study, since the researcher was able to successfully perform the research study. According to the dictionary unit of South African English (2009:307), in Chapter 5, section 5.6, "delimitation or delimit" refers to determining the limits or boundaries of a thing or project. In this study, data were collected from all six areas of the PetroSA GTL Refinery, namely Air and Gas Separation, Reforming, Synthol, Refinery, Blending and Storage and Offsites and Utilities. Permission to utilise certain types of data and information was granted to the researcher. The MS assessment tool was successfully utilised to perform this study. As mentioned above, the data collected presented a "snapshot" and the "depth", which presents an opportunity for research to be repeated. The research study excluded Head Office, depots, Orca, Voorbaai, Logistics Base and the FA Platform.

It is also necessary to highlight the limitations of the study, since there were several notable limitations that affected the researcher's ability and timing to perform this research study. First, there was no ideal model or tool that could be used to measure the MMS and PO&P, although the MS assessment tool seemed to be the most widely used or applied globally. Further investigation, using a different assessment tool to assess the MMS and PO&P at the Refinery, could yield different—or similar—results. Future research would be worthwhile using a different research instrument to confirm or verify research study findings.

Second, the data was collected and captured in a relatively short period and presented a "snapshot" as opposed to a trend, hence the "depth" not the "width" of the data were investigated. Future research would be worthwhile to use longitudinal methodology in data collection thus to represent the “width” instead of the current “depth”. Third, as indicated before, the study excluded Head Office, depots, Orca, Logistics Base and the FA Platform at the PetroSA GTL Refinery; the findings cannot, therefore, be generalised to all areas in the Refinery. Future research would be worthwhile to indicate perceptions and expectations of the above areas.

Fourth, the rules, regulations and policies of the Refinery regarding handling of data and information made it difficult for the researcher to include or use specific data that is termed confidential by the company.

Last, management may have felt uncomfortable that the respondents and their subordinates participated in this survey, hence the norm is to maintain confidentiality and not to make public, share or communicate data or information. Future research would be worthwhile, hence the researcher is confident that after receiving, reading and understanding this research study, there is a possibility that management would give more access to classified data and information and that management would encourage more participation.

The outcomes or results of this study would not differ radically even if the above areas are included. Therefore generalisation of these results to all areas of the PetroSA GTL Refinery cannot be ruled out, although the perceptions and expectations of respondents in these areas could either be the same or differ.

7.6 RESEARCH CONCLUSIONS

While reviewing the literature, it was evident that a limited amount of research was conducted on the impact of the MMS on PO&P. To the best of the researcher’s knowledge, this is the first study to be conducted to investigate the impact of the MMS on PO&P, especially at the PetroSA GTL Refinery. It is therefore believed that the findings of this research study could serve as the basis for future studies on MMS and PO&P. The empirical findings suggested that there is a moderate positive linear relationship between the MMS and PO&P. In Chapter 6, section 6.6, the average Pearson product moment correlation coefficient (r) was calculated as 0.787 and the coefficient of determination (R^2) was calculated as 0.619 (61.9%). According to the data and information in Chapter 5, section 5.4, Table 5.7, 0.619 represented a moderate positive linear relationship between the MMS and PO&P. This indicated that the MMS (independent variable) explains, influences and impacts 61.9% of the variation in PO&P (dependent variable) of the PetroSA GTL Refinery. The impact, influence and explanation of PO&P can be viewed with a moderate degree of confidence, since 38.1% of the variation in PO&P is not influenced, explained or impacted by the MMS.

As indicated in Chapter 2, sections 2.1.1 and 2.1.2 and Figure 2.2, more work is needed to improve the body of knowledge specifically on asset management, which is the pillar of asset health; asset performance and asset provision. This area will enable development of skills and knowledge in the fields of maintenance, production and MMS and enable development of these as a unit, instead of separating them or threating them individually, as in Figure 2.2 in Chapter 2.

7.7 RESEARCH RECOMMENDATIONS

In Chapter 6, sections 6.3.2 and 6.3.3, Figures 6.3 and 6.4 provided the average means for both the production and maintenance groups. In addition, Tables 6.5 and 6.6 in Chapter 6, section 6.4.7 indicate that the production perspective (asset health), learning and growth (skills and working conditions) and the safety perspective (asset prioritisation) represent the largest PO&P gap. Based on the three identified gaps, it is recommended that the PetroSA GTL Refinery management considers the following steps to improve and enhance these perspectives/dimensions:

(1) Production perspective (asset health): The following represents 20% of activities according to the Pareto principle that, when positively addressed, will result in 80% positive results (improvement):

- Compile, issue and communicate the production plan and schedule;
- Improve maintenance and asset management of the plant and equipment to reduce failures and breakdowns;
- Ensure that planned and scheduled PO targets are met through vigorous production planning, scheduling, monitoring and control;

- Ensure that production is planned and scheduled in line with the plant and equipment capacity and
- Enhance organisational structure and size to allow decision making at a lower level of management, to establish communication channels to support speedy information flow/transmission and to enable supervisors to perform minimum administrative functions.

(2) Learning and growth perspective (skills and working conditions): The following represents 20% of activities that, when positively addressed, will result in 80% positive results (improvement) according to the Pareto principle:

- Enhance maintenance scheduling and coordination by improving work prioritisation systems; completing planned and scheduled work on time; effective utilisation of manpower and effective coordination and control of support services such as scaffolding, high pressure cleaning, rigging, cranes and workshops and
- Ensure that artisans, technicians, engineers, operators, superintendents, inspectors and specialists are cross trained.

(3) Safety perspective (asset prioritisation): The following represents the 20% of activities according to the Pareto principle that, when positively addressed, will result in 80% positive results (improvement):

- Ensure compliance with regulatory requirements by performing timely risk based inspections on pressure safety valves, vessels and pipelines and
- Enhance maintenance work measurement by implementing and maintaining visual planning boards, compiling and communicating KPI trend reports, capacity plans and effective utilisation of resources.

As indicated in Chapter 5, section 5.2, this study followed a cross sectional design. This provides a solid foundation for further research to conduct a similar study following a longitudinal method where a single group of people is observed over a period. These recommendations were made with reference to the literature and the findings of the empirical study.

This chapter concludes the study by summarising the findings and discussing the reliability and validity of the research, delimitations, limitations, conclusions drawn and recommendations made for possible future research in this area. In closing, it would be beneficial to repeat this study to indicate all areas at the PetroSA GTL Refinery (Head Office, Orca, Logistics Base and the FA Platform) in order to obtain a wider view of the impact of the MMS on PO&P.

7.8 CHAPTER SUMMARY

This chapter provided an overview of the research study and the schematic diagram depicting the steps followed to investigate the research study, which was displayed in section 7.2. It also highlighted the main findings of the research study with the emphasis on the primary and secondary objectives. The chapter briefly detailed the reliability and validity of the research results. A detailed discussion on the delimitations and limitations of the research study followed.

The chapter discussed and addressed the research conclusions with the emphasis on the findings of the study and contributions to the body of knowledge. The chapter concluded with discussion of the research recommendations with the emphasis on the three gaps identified gaps, namely production perspective, safety perspective and learning and growth perspective.

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APPENDIX A: REQUEST TO PARTICIPATE IN AND COMPLETE RESEARCH QUESTIONNAIRES

Research Study: The Impact of the MMS on PO and Profitability at the PetroSA GTL Refinery

Research conducted by: Bafana Mahlangu
Designation: Planning Engineer

Dear Respondent

You are invited to participate in an academic research study conducted by Bafana Mahlangu, who is a Planning Engineer in the Projects and Planning Department at the PetroSA GTL Refinery.

The purpose of the study is to explore the level of maintenance (asset) management at the Refinery and the impact thereof on the PO and profitability of the company. Please note the following:

> This study is an anonymous survey, that is, your name will not appear on the questionnaire and the answers you give will be treated as strictly confidential. You cannot be identified in person, based on the answers you give.
>
> Please answer the questions in the attached questionnaire as completely and honestly as possible. This should not take more than fifteen (15) minutes of your time.
>
> The results of the study will be used for academic purposes only and may be published in an academic journal. I will provide you with a summary of my findings on request.
>
> Please do not hesitate to contact me if you have any questions or comments regarding the study.

Thanking you in advance for your contribution to this research.

Kind regards

Bafana Mahlangu

Planning Engineer

Projects and Planning Department

Tel: (044) 601-2940

Cell: 074 374 3813

Email (W): Bafana.mahlangu@petrosa.co.za (H): Khulu@webmail.co.za

APPENDIX B: DEMOGRAPHICS

PLEASE COMPLETE THE FOLLOWING BY MARKING THE APPROPRIATE BLOCK

Designation

Artisan ☐

Technician/Technologist ☐

Engineer/Superintendent ☐

Supervisor/Foreman ☐

Manager/Executive ☐

Official/Specialist ☐

Operator/Controller ☐

Planner ☐

Department

Maintenance ☐

Operations ☐

Area

AGS	☐	RFM	☐	SNT	☐
REF	☐	B&S	☐	O&U	☐

APPENDIX C: MAINTENANCE SCORECARD (MS) QUESTIONNAIRE FOR PRODUCTION OUTPUT (PO) AND PROFITABILITY

Please read the following guidelines and answer ALL the questions below.

The questions require you to evaluate the impact of PO and profitability at the PetroSA GTL Refinery. Statements regarding PO and profitability are provided; please indicate your perception and expectation of the impact of the PO and profitability at the PetroSA GTL Refinery by circling or putting a circle on a number provided on the columns below. Rating is as follows:

5 = Strongly Agree
4 = Agree
3 = Neutral
2 = Disagree
1 = Strongly Disagree

Item No	Statement	Perception Rating						Expectation Rating				
1.0	**PO Perspective**											
1.1	Production plan and schedule is compiled, issued and communicated	1	2	3	4	5		1	2	3	4	5
1.2	Production volumes are reduced due to plant/equipment failure or breakdown	1	2	3	4	5		1	2	3	4	5
1.3	Daily, weekly and monthly PO is within the scheduled or planned target	1	2	3	4	5		1	2	3	4	5
1.4	PO is planned and scheduled as per machine, plant or equipment capacity	1	2	3	4	5		1	2	3	4	5
1.5	Machines, plant or equipment produce as per design capacity	1	2	3	4	5		1	2	3	4	5
1.6	Plant or equipment is always	1	2	3	4	5		1	2	3	4	5

Item No	Statement	Perception Rating						Expectation Rating				
	available after maintenance work is done on it											
1.7	Plant or equipment is always reliable after maintenance work is done on it	1	2	3	4	5		1	2	3	4	5
1.8	Plant or equipment is always operable and efficient after maintenance work is done on it	1	2	3	4	5		1	2	3	4	5
2.0	**Quality Perspective**											
2.1	Manufactured products are within required specification	1	2	3	4	5		1	2	3	4	5
2.2	Product quality is consistent	1	2	3	4	5		1	2	3	4	5
2.3	Plant or equipment failure or breakdowns contribute to poor product quality and production delays	1	2	3	4	5		1	2	3	4	5
2.4	Plant or equipment availability and reliability contribute to poor product quality and production delays	1	2	3	4	5		1	2	3	4	5
2.5	Lack of skills, competencies and experience contributes to poor product quality and production delays	1	2	3	4	5		1	2	3	4	5
2.6	Maintenance and production reworks contribute to production delays	1	2	3	4	5		1	2	3	4	5
3.0	**Cost Perspective**											
3.1	Product prices are reduced due to poor production quality	1	2	3	4	5		1	2	3	4	5
3.2	Sale or delivery of products to customers is delayed due to plant/equipment failure or breakdown	1	2	3	4	5		1	2	3	4	5
3.3	Company loses income or revenue due to low production volumes	1	2	3	4	5		1	2	3	4	5
3.4	Company loses income or money due to plant/equipment failure or breakdowns	1	2	3	4	5		1	2	3	4	5

Item No	Statement	Perception Rating						Expectation Rating				
3.5	Weekly, monthly and yearly income or revenue is within the set targets	1	2	3	4	5		1	2	3	4	5
3.6	Maintenance and production reworks contribute to the loss of production and revenue/income	1	2	3	4	5		1	2	3	4	5
4.0	**Safety Perspective**											
4.1	There are no overdue RBI inspections for main equipment	1	2	3	4	5		1	2	3	4	5
4.2	There are no overdue RBI inspections for PSV's	1	2	3	4	5		1	2	3	4	5
4.3	There are no overdue RBI inspections for Pipeline (QP's)	1	2	3	4	5		1	2	3	4	5
4.4	There are no minor injuries in my area for the year 2014	1	2	3	4	5		1	2	3	4	5
4.5	There are no lost time injuries in my area for the year 2014	1	2	3	4	5		1	2	3	4	5
4.6	The level of absenteeism is acceptable in my area	1	2	3	4	5		1	2	3	4	5
5.0	**Environmental Perspective**											
5.1	There is no product major spillage in my area for the year 2014	1	2	3	4	5		1	2	3	4	5
5.2	There is no product minor spillage in my area for the year 2014	1	2	3	4	5		1	2	3	4	5
5.3	There are no priority 1 overdue incidents for production plant or equipment	1	2	3	4	5		1	2	3	4	5
6.0	**Learning and Growing Perspective**											
6.1	There are sufficient cross trained artisans to balance work load in my area	1	2	3	4	5		1	2	3	4	5
6.2	There are sufficient cross trained operators to balance work load in my area	1	2	3	4	5		1	2	3	4	5
6.3	There are sufficient cross	1	2	3	4	5		1	2	3	4	5

Item No	Statement	Perception Rating						Expectation Rating				
	trained technicians to balance work load in my area											
6.4	There are sufficient cross trained engineers to balance work load in my area	1	2	3	4	5		1	2	3	4	5
6.5	There are sufficient cross trained supervisors to balance work load in my area	1	2	3	4	5		1	2	3	4	5
6.6	There are sufficient cross trained Inspectors to balance work load in my area	1	2	3	4	5		1	2	3	4	5

APPENDIX D: MAINTENANCE SCORECARD (MS) QUESTIONNAIRE FOR PRODUCTION OUTPUT (PO) AND PROFITABILITY

Please read the following guidelines and answer ALL the questions below.

The questions require you to evaluate the impact of maintenance management system (MMS) on production output (PO) and profitability at the PetroSA GTL Refinery. Statements regarding MMS are provided; please indicate your perception of the impact of the MMS and your expectation of the MMS at the PetroSA GTL Refinery by circling or putting a circle on a number provided on the columns. Rating is as follows:

5 = Strongly Agree
4 = Agree
3 = Neutral
2 = Disagree
1 = Strongly Disagree

Item No	Statement	Perception Rating						Expectation Rating				
1.0	Organisational Structure and Size											
1.1	Decisions can be made and carried out at the lowest appropriate level	1	2	3	4	5		1	2	3	4	5
1.2	Supervisors are not so overloaded with administrative or other duties that performance of their direct supervisory duties is hampered	1	2	3	4	5		1	2	3	4	5
1.3	There are sufficient cross trained artisans, technicians and engineers to provide quality maintenance management service	1	2	3	4	5		1	2	3	4	5
1.4	Communication channels and procedures are designed for clear and quick transmission of information	1	2	3	4	5		1	2	3	4	5
1.5	Relationships with staff	1	2	3	4	5		1	2	3	4	5

Item No	Statement	Perception Rating						Expectation Rating				
	departments such as Procurement, stores, finance and others are clearly defined											
2.0	Computer Information and Support											
2.1	The MMS is computerised	1	2	3	4	5		1	2	3	4	5
2.2	The right maintenance information is available to all levels of the organisation	1	2	3	4	5		1	2	3	4	5
2.3	Information is complete and reliable	1	2	3	4	5		1	2	3	4	5
2.4	Monthly maintenance cost reports are compiled and readily available	1	2	3	4	5		1	2	3	4	5
2.5	Information, data and history is accessible, retrievable and user friendly	1	2	3	4	5		1	2	3	4	5
3.0	Work / Job Planning											
3.1	Weekly and monthly look ahead plans are compiled, approved and communicated	1	2	3	4	5		1	2	3	4	5
3.2	Policy specifies how detailed planning of selected maintenance work is done and a target has be established	1	2	3	4	5		1	2	3	4	5
3.3	The concept of maintenance planning is fully accepted by maintenance supervisors	1	2	3	4	5		1	2	3	4	5
3.4	Planning procedures are well documented	1	2	3	4	5		1	2	3	4	5
3.5	All shutdown work is pre-planned	1	2	3	4	5		1	2	3	4	5
3.6	Short and long term outage plans are compiled, approved and communicated	1	2	3	4	5		1	2	3	4	5
4.0	Maintenance Work Measurement											
4.1	Weekly maintenance Key Performance indicators (KPIs) are compiled, issued and communicated	1	2	3	4	5		1	2	3	4	5
4.2	Monthly maintenance KPIs are	1	2	3	4	5		1	2	3	4	5

Item No	Statement	Perception Rating						Expectation Rating				
	compiled, issued and communicated											
4.3	Visual planning boards are updated weekly	1	2	3	4	5		1	2	3	4	5
4.4	KPI trends are discussed bi-monthly, corrective and preventive measures devised and taken	1	2	3	4	5		1	2	3	4	5
4.5	Capacity plans are compiled and issued weekly	1	2	3	4	5		1	2	3	4	5
4.6	Maintenance KPIs add value to improvement of MMS	1	2	3	4	5		1	2	3	4	5
5.0	Material Support and Control											
5.1	Minimum and maximum Inventory/stock levels are defined or set	1	2	3	4	5		1	2	3	4	5
5.2	Stock taking/cycle counting is used to preserve reliability of stock/inventory records	1	2	3	4	5		1	2	3	4	5
5.3	An intelligent part numbering system is utilised	1	2	3	4	5		1	2	3	4	5
5.4	Usage records are employed to determine stock levels order points and order quantities	1	2	3	4	5		1	2	3	4	5
5.5	Maintenance, Procurement, Finance and Stores, work together to assure availability of necessary parts; elimination of obsolete parts, adjustment of stock levels	1	2	3	4	5		1	2	3	4	5
6.0	Maintenance Scheduling and Coordination											
6.1	The system of work prioritisation effectively distinguish between legitimate rush jobs and those which can be planned	1	2	3	4	5		1	2	3	4	5
6.2	Scheduled jobs start and completion dates, resource allocation and duration are published, distributed and communicated	1	2	3	4	5		1	2	3	4	5

Item No	Statement	Perception Rating						Expectation Rating				
6.3	Schedule compliance substantiated by KPI report is high	1	2	3	4	5		1	2	3	4	5
6.4	Planned and scheduled work is completed on time and substantiated by KPI report	1	2	3	4	5		1	2	3	4	5
6.5	Procedure for requesting, coordinating and controlling support services such as scaffolding; HP cleaning; rigging; cranes and workshops is effective	1	2	3	4	5		1	2	3	4	5

APPENDIX E: COMBINED AREAS MEANS, STANDARD DEVIATIONS AND GAP FOR THE PRODUCTION GROUP

		Valid N	Perception		Expectation		
			Mean-(P)	STDev	Mean-(E)	STDev	Gap
s1.1	Production plan and schedule is compiled, issued and communicated	**38**	3.868	1.070	4.053	0.517	-0.19
s1.2	Production volumes are reduced due to plant/equipment failure or breakdown	**38**	3.711	1.088	3.895	0.559	-0.18
s1.3	Daily, weekly and monthly PO is within the scheduled or planned target	**38**	3.000	0.900	3.947	0.567	-0.95
s1.4	PO is planned and scheduled as per machine, plant or equipment capacity	**38**	3.342	0.909	3.711	0.515	-0.37
s1.5	Machines, plant or equipment produce as per design capacity	**38**	2.842	0.973	3.868	0.529	-1.03
s1.6	Plant or equipment is always available after maintenance work is done on it	**38**	2.868	0.991	3.816	0.563	-0.95
s1.7	Plant or equipment is always reliable after maintenance work is done on it	**38**	2.816	1.036	3.632	0.541	-0.82
s1.8	Plant or equipment is always operable and efficient after maintenance work is done on it	**38**	2.842	1.079	3.895	0.649	-1.05
s2.1	Manufactured products are within required specification	**38**	3.865	0.948	4.105	0.509	-0.24
s2.2	Product quality is consistent	**38**	3.459	0.803	3.974	0.592	-0.52
s2.3	Plant or equipment failure or breakdowns contribute to poor product quality and production delays	**38**	3.919	0.924	4.026	0.492	-0.11
s2.4	Plant or equipment availability and reliability contribute to poor product quality and production delays	**38**	3.757	0.925	4.026	0.492	-0.27
s2.5	Lack of skills, competencies and experience contributes to poor product quality and production delays	**38**	3.784	1.158	3.974	0.434	-0.19
s2.6	Maintenance and production reworks contribute to production delays	**38**	4.135	0.822	4.026	0.492	0.11
s3.1	Product prices are reduced due to poor production quality	**38**	3.500	1.089	4.079	0.539	-0.58
s3.2	Sale or delivery of products to customers is delayed due to plant/equipment failure or breakdown	**38**	3.972	0.774	4.132	0.529	-0.16

		Valid N	Perception		Expectation		
			Mean-(P)	STDev	Mean-(E)	STDev	Gap
s3.3	Company loses income or revenue due to low production volumes	**38**	4.333	0.756	4.026	0.434	0.31
s3.4	Company loses income or money due to plant/equipment failure or breakdowns	**38**	4.111	0.820	4.026	0.434	0.09
s3.5	Weekly, monthly and yearly income or revenue is within the set targets	**38**	3.167	0.878	3.921	0.487	-0.75
s3.6	Maintenance and production reworks contribute to the loss of production and revenue/income	**38**	4.056	0.791	4.447	0.504	-0.39
s4.1	There are no overdue RBI inspections for main equipment	**38**	2.474	0.893	3.684	0.662	-1.21
s4.2	There are no overdue RBI inspections for PSV's	**38**	2.500	0.952	3.519	0.599	-1.02
s4.3	There are no overdue RBI inspections for Pipeline (QP's)	**38**	2.553	0.921	3.658	0.627	-1.11
s4.4	There are no minor injuries in my area for the year 2014	**38**	3.026	1.127	3.711	0.694	-0.69
s4.5	There are no lost time injuries in my area for the year 2014	**38**	3.526	1.224	3.711	0.515	-0.19
s4.6	The level of absenteeism is acceptable in my area	**38**	2.895	1.226	3.684	0.525	-0.79
s5.1	There is no product major spillage in my area for the year 2014	**38**	3.405	1.092	3.842	0.547	-0.44
s5.2	There is no product minor spillage in my area for the year 2014	**38**	3.135	1.159	3.605	0.495	-0.47
s5.3	There are no priority 1 overdue incidents for production plant or equipment	**38**	3.243	0.796	3.816	0.652	-0.57
s6.1	There are sufficient cross trained artisans to balance work load in my area	**38**	3.083	0.841	3.868	0.665	-0.79
s6.2	There are sufficient cross trained operators to balance work load in my area	**38**	2.972	0.971	3.711	0.654	-0.74
s6.3	There are sufficient cross trained technicians to balance work load in my area	**38**	3.139	0.762	3.842	0.679	-0.70
s6.4	There are sufficient cross trained engineers to balance work load in my area	**38**	3.000	0.717	3.842	0.495	-0.84
s6.5	There are sufficient cross trained supervisors to balance work load in my area	**38**	3.111	0.887	3.763	0.634	-0.65

		Valid N	Perception		Expectation		
			Mean-(P)	STDev	Mean-(E)	STDev	Gap
s6.6	There are sufficient cross trained Inspectors to balance work load in my area	**38**	3.000	0.676	3.789	0.622	-0.79
	POI	**38**	**3.326**	**0.942**	**3.875**	**0.556**	**-0.560**
	Pearson product moment Correlation [r]		**0.773**				
	Coefficient of Determinant [R Squared]		**0.597**	**60%**			

APPENDIX F: AIR & GAS SEPARATION MEANS, STANDARD DEVIATIONS AND GAP FOR THE PRODUCTION GROUP

		Valid N	Perception		Expectation		
			Mean-P	StDev	Mean-E	StDev	Gap
s1.1	Production plan and schedule is compiled, issued and communicated	7	4.000	1.155	3.714	0.577	0.29
s1.2	Production volumes are reduced due to plant/equipment failure or breakdown	7	4.000	1.000	3.857	0.756	0.14
s1.3	Daily, weekly and monthly PO is within the scheduled or planned target	7	2.429	0.976	3.429	0.690	-1.00
s1.4	PO is planned and scheduled as per machine, plant or equipment capacity	7	3.286	1.113	3.571	0.535	-0.29
s1.5	Machines, plant or equipment produce as per design capacity	7	2.286	0.756	3.429	0.535	-1.14
s1.6	Plant or equipment is always available after maintenance work is done on it	7	2.429	0.787	3.286	0.535	-0.86
s1.7	Plant or equipment is always reliable after maintenance work is done on it	7	2.429	0.976	3.714	0.488	-1.29
s1.8	Plant or equipment is always operable and efficient after maintenance work is done on it	7	2.143	1.069	3.857	0.756	-1.71
s2.1	Manufactured products are within required specification	7	3.000	1.528	4.000	0.690	-1.00
s2.2	Product quality is consistent	7	3.143	0.900	3.714	0.816	-0.57
s2.3	Plant or equipment failure or breakdowns contribute to poor product quality and production delays	7	3.429	1.272	4.143	0.488	-0.71
s2.4	Plant or equipment availability and reliability contribute to poor product quality and production delays	7	3.571	1.134	3.714	0.690	-0.14
s2.5	Lack of skills, competencies and experience contributes to poor product quality and production delays	7	3.286	1.496	3.857	0.488	-0.57
s2.6	Maintenance and production reworks contribute to production delays	7	3.714	1.380	4.000	0.690	-0.29
s3.1	Product prices are reduced due to poor production quality	7	3.714	1.380	4.286	0.816	-0.57
s3.2	Sale or delivery of products to customers is delayed due to plant/equipment failure or breakdown	7	3.857	0.900	4.000	0.756	-0.14

		Valid N	Perception		Expectation		
			Mean-P	StDev	Mean-E	StDev	Gap
s3.3	Company loses income or revenue due to low production volumes	**7**	3.857	1.215	3.857	0.577	0.00
s3.4	Company loses income or money due to plant/equipment failure or breakdowns	**7**	4.143	1.069	4.000	0.690	0.14
s3.5	Weekly, monthly and yearly income or revenue is within the set targets	**7**	3.429	0.787	4.000	0.816	-0.57
s3.6	Maintenance and production reworks contribute to the loss of production and revenue/income	**7**	4.143	0.690	4.714	0.488	-0.57
s4.1	There are no overdue RBI inspections for main equipment	**7**	2.571	0.976	4.000	0.816	-1.43
s4.2	There are no overdue RBI inspections for PSV's	**7**	2.714	1.254	3.857	0.690	-1.14
s4.3	There are no overdue RBI inspections for Pipeline (QP's)	**7**	2.857	0.900	3.571	0.976	-0.71
s4.4	There are no minor injuries in my area for the year 2014	**7**	3.429	0.976	3.571	1.134	-0.14
s4.5	There are no lost time injuries in my area for the year 2014	**7**	4.143	0.690	3.857	0.690	0.29
s4.6	The level of absenteeism is acceptable in my area	**7**	3.000	1.414	3.571	0.787	-0.57
s5.1	There is no product major spillage in my area for the year 2014	**7**	3.714	1.254	4.000	0.816	-0.29
s5.2	There is no product minor spillage in my area for the year 2014	**7**	3.286	1.380	3.571	0.535	-0.29
s5.3	There are no priority 1 overdue incidents for production plant or equipment	**7**	3.286	0.756	3.571	0.976	-0.29
s6.1	There are sufficient cross trained artisans to balance work load in my area	**7**	3.000	0.577	4.000	4.000	-1.00
s6.2	There are sufficient cross trained operators to balance work load in my area	**7**	2.714	0.951	3.571	0.535	-0.86
s6.3	There are sufficient cross trained technicians to balance work load in my area	**7**	3.143	0.378	3.714	0.951	-0.57
s6.4	There are sufficient cross trained engineers to balance work load in my area	**7**	2.714	0.488	3.714	0.488	-1.00
s6.5	There are sufficient cross trained supervisors to balance work load in my area	**7**	3.000	0.577	3.571	0.787	-0.57
s6.6	There are sufficient cross trained Inspectors to balance work load in my area	**7**	2.714	0.488	3.286	0.756	-0.57

		Valid N	Perception		Expectation		
			Mean-P	StDev	Mean-E	StDev	Gap
	POI	**7**	**3.216**	**0.990**	**3.788**	**0.795**	**-0.596**

APPENDIX G: REFORMING MEANS, STANDARD DEVIATIONS GAP FOR THE PRODUCTION GROUP

		Valid N	Perception		Expectation		
			Mean-(P)	STDev	Mean -(E)	STDev	Gap
s1.1	Production plan and schedule is compiled, issued and communicated	**5**	3.600	1.673	3.800	0.447	-0.20
s1.2	Production volumes are reduced due to plant/equipment failure or breakdown	**5**	3.600	1.673	3.800	0.447	-0.20
s1.3	Daily, weekly and monthly PO is within the scheduled or planned target	**5**	3.200	1.304	3.800	0.447	-0.60
s1.4	PO is planned and scheduled as per machine, plant or equipment capacity	**5**	3.400	1.140	3.800	0.447	-0.40
s1.5	Machines, plant or equipment produce as per design capacity	**5**	3.600	0.894	4.000	0.000	-0.40
s1.6	Plant or equipment is always available after maintenance work is done on it	**5**	3.400	0.548	4.000	0.000	-0.60
s1.7	Plant or equipment is always reliable after maintenance work is done on it	**5**	3.200	1.095	3.800	0.447	-0.60
s1.8	Plant or equipment is always operable and efficient after maintenance work is done on it	**5**	3.200	1.095	3.800	0.447	-0.60
s2.1	Manufactured products are within required specification	**5**	4.200	0.837	4.000	0.000	0.20
s2.2	Product quality is consistent	**5**	4.000	0.707	4.000	0.000	0.00
s2.3	Plant or equipment failure or breakdowns contribute to poor product quality and production delays	**5**	3.800	1.095	4.000	0.000	-0.20
s2.4	Plant or equipment availability and reliability contribute to poor product quality and production delays	**5**	3.000	1.225	3.800	0.447	-0.80
s2.5	Lack of skills, competencies and experience contributes to poor product quality and production delays	**5**	3.000	0.707	4.000	0.000	-1.00
s2.6	Maintenance and production reworks contribute to production delays	**5**	4.200	0.837	4.000	0.000	0.20
s3.1	Product prices are reduced due to poor production quality	**5**	3.600	1.140	4.200	0.447	-0.60
s3.2	Sale or delivery of products to customers is delayed due to plant/equipment failure or breakdown	**5**	4.200	0.837	4.200	0.447	0.00
s3.3	Company loses income or revenue due to low production volumes	**5**	4.600	0.548	4.000	0.000	0.60

		Valid N	Perception		Expectation		
			Mean-(P)	**STDev**	**Mean -(E)**	**STDev**	**Gap**
s3.4	Company loses income or money due to plant/equipment failure or breakdowns	**5**	4.000	0.707	4.200	0.447	-0.20
s3.5	Weekly, monthly and yearly income or revenue is within the set targets	**5**	4.000	0.707	4.000	0.000	0.00
s3.6	Maintenance and production reworks contribute to the loss of production and revenue/income	**5**	3.800	0.447	4.800	0.447	-1.00
s4.1	There are no overdue RBI inspections for main equipment	**5**	2.000	0.707	3.200	0.447	-1.20
s4.2	There are no overdue RBI inspections for PSV's	**5**	2.000	0.707	3.200	0.447	-1.20
s4.3	There are no overdue RBI inspections for Pipeline (QP's)	**5**	2.400	1.140	3.800	0.447	-1.40
s4.4	There are no minor injuries in my area for the year 2014	**5**	3.600	1.517	3.800	0.447	-0.20
s4.5	There are no lost time injuries in my area for the year 2014	**5**	3.600	1.517	3.600	0.548	0.00
s4.6	The level of absenteeism is acceptable in my area	**5**	2.400	1.517	3.600	0.548	-1.20
s5.1	There is no product major spillage in my area for the year 2014	**5**	3.400	1.517	3.800	0.447	-0.40
s5.2	There is no product minor spillage in my area for the year 2014	**5**	3.800	1.308	3.600	0.548	0.20
s5.3	There are no priority 1 overdue incidents for production plant or equipment	**5**	3.400	1.342	3.800	0.447	-0.40
s6.1	There are sufficient cross trained artisans to balance work load in my area	**5**	4.000	0.707	4.400	0.548	-0.40
s6.2	There are sufficient cross trained operators to balance work load in my area	**5**	3.600	1.140	3.800	0.837	-0.20
s6.3	There are sufficient cross trained technicians to balance work load in my area	**5**	3.600	1.140	4.000	0.707	-0.40
s6.4	There are sufficient cross trained engineers to balance work load in my area	**5**	3.600	1.140	4.000	0.707	-0.40
s6.5	There are sufficient cross trained supervisors to balance work load in my area	**5**	4.000	0.707	4.200	0.447	-0.20
s6.6	There are sufficient cross trained Inspectors to balance work load in my area	**5**	3.800	0.837	4.000	0.707	-0.20
	POI	**5**	**3.509**	**1.033**	**3.909**	**0.377**	**-0.406**

APPENDIX H: SYNTHOL MEANS, STANDARD DEVIATIONS GAP FOR THE PRODUCTION GROUP

		Valid N	Perception		Expectation		
			Mean-(P)	STDev	Mean -(E)	STDev	Gap
s1.1	Production plan and schedule is compiled, issued and communicated	**8**	4.250	0.463	4.375	0.518	-0.13
s1.2	Production volumes are reduced due to plant/equipment failure or breakdown	**8**	3.500	1.195	4.000	0.535	-0.50
s1.3	Daily, weekly and monthly PO is within the scheduled or planned target	**8**	3.750	0.707	4.125	0.641	-0.38
s1.4	PO is planned and scheduled as per machine, plant or equipment capacity	**8**	3.500	0.926	3.750	0.463	-0.25
s1.5	Machines, plant or equipment produce as per design capacity	**8**	2.375	0.916	4.125	0.641	-1.75
s1.6	Plant or equipment is always available after maintenance work is done on it	**8**	3.000	0.926	4.000	0.535	-1.00
s1.7	Plant or equipment is always reliable after maintenance work is done on it	**8**	3.000	0.926	3.750	0.463	-0.75
s1.8	Plant or equipment is always operable and efficient after maintenance work is done on it	**8**	3.000	0.756	4.000	0.756	-1.00
s2.1	Manufactured products are within required specification	**8**	4.000	0.535	4.125	0.354	-0.13
s2.2	Product quality is consistent	**8**	3.250	0.463	3.875	0.354	-0.63
s2.3	Plant or equipment failure or breakdowns contribute to poor product quality and production delays	**8**	3.875	0.991	4.125	0.354	-0.25
s2.4	Plant or equipment availability and reliability contribute to poor product quality and production delays	**8**	4.125	0.641	3.875	0.354	0.25
s2.5	Lack of skills, competencies and experience contributes to poor product quality and production delays	**8**	4.125	1.126	4.125	0.354	0.00
s2.6	Maintenance and production reworks contribute to production delays	**8**	4.000	0.756	4.000	0.000	0.00
s3.1	Product prices are reduced due to poor production quality	**8**	3.375	1.188	4.250	0.463	-0.88
s3.2	Sale or delivery of products to customers is delayed due to plant/equipment failure or breakdown	**8**	3.875	0.641	4.250	0.463	-0.38

		Valid N	Perception		Expectation		
			Mean-(P)	STDev	Mean -(E)	STDev	Gap
s3.3	Company loses income or revenue due to low production volumes	**8**	4.250	0.707	4.250	0.463	0.00
s3.4	Company loses income or money due to plant/equipment failure or breakdowns	**8**	4.000	0.756	4.125	0.354	-0.13
s3.5	Weekly, monthly and yearly income or revenue is within the set targets	**8**	2.625	0.916	3.750	0.463	-1.13
s3.6	Maintenance and production reworks contribute to the loss of production and revenue/income	**8**	4.125	0.835	4.250	0.463	-0.13
s4.1	There are no overdue RBI inspections for main equipment	**8**	2.375	0.744	3.500	0.535	-1.13
s4.2	There are no overdue RBI inspections for PSV's	**8**	2.250	0.707	3.500	0.535	-1.25
s4.3	There are no overdue RBI inspections for Pipeline (QPs)	**8**	2.125	0.835	3.750	0.463	-1.63
s4.4	There are no minor injuries in my area for the year 2014	**8**	2.750	1.488	3.500	0.535	-0.75
s4.5	There are no lost time injuries in my area for the year 2014	**8**	2.875	1.458	3.500	0.535	-0.63
s4.6	The level of absenteeism is acceptable in my area	**8**	2.875	1.126	3.500	0.535	-0.63
s5.1	There is no product major spillage in my area for the year 2014	**8**	2.889	0.928	3.500	0.535	-0.61
s5.2	There is no product minor spillage in my area for the year 2014	**8**	2.222	1.093	3.375	0.518	-1.15
s5.3	There are no priority 1 overdue incidents for production plant or equipment	**8**	3.222	0.833	3.500	0.535	-0.28
s6.1	There are sufficient cross trained artisans to balance work load in my area	**8**	3.000	1.000	3.750	0.707	-0.75
s6.2	There are sufficient cross trained operators to balance work load in my area	**8**	3.000	0.866	3.750	0.707	-0.75
s6.3	There are sufficient cross trained technicians to balance work load in my area	**8**	3.222	0.667	3.750	0.707	-0.53
s6.4	There are sufficient cross trained engineers to balance work load in my area	**8**	3.333	0.707	4.000	0.535	-0.67
s6.5	There are sufficient cross trained supervisors to balance work load in my area	**8**	3.111	0.928	3.875	0.644	-0.76
s6.6	There are sufficient cross trained Inspectors to balance work load in my area	**8**	3.000	0.707	4.000	0.535	-1.00

		Valid N	Perception		Expectation		
			Mean-(P)	STDev	Mean -(E)	STDev	Gap
	POI	**8**	**3.264**	**0.870**	**3.882**	**0.501**	**-0.632**

APPENDIX I: REFINERY MEANS, STANDARD DEVIATIONS GAP FOR THE PRODUCTION GROUP

		Valid N	Perception		Expectation		
			Mean-(P)	STDev	Mean-(E)	STDev	Gap
s1.1	Production plan and schedule is compiled, issued and communicated	**8**	3.625	1.408	3.875	0.641	-0.25
s1.2	Production volumes are reduced due to plant/equipment failure or breakdown	**8**	3.625	1.302	3.875	0.641	-0.25
s1.3	Daily, weekly and monthly PO is within the scheduled or planned target	**8**	3.000	0.926	3.625	0.518	-0.63
s1.4	PO is planned and scheduled as per machine, plant or equipment capacity	**8**	2.875	0.835	3.500	0.535	-0.63
s1.5	Machines, plant or equipment produce as per design capacity	**8**	3.125	1.126	3.750	0.463	-0.63
s1.6	Plant or equipment is always available after maintenance work is done on it	**8**	2.750	1.389	3.625	0.518	-0.88
s1.7	Plant or equipment is always reliable after maintenance work is done on it	**8**	2.375	1.188	3.500	0.535	-1.13
s1.8	Plant or equipment is always operable and efficient after maintenance work is done on it	**8**	2.750	1.389	3.750	0.707	-1.00
s2.1	Manufactured products are within required specification	**8**	4.125	0.641	4.125	0.354	0.00
s2.2	Product quality is consistent	**8**	3.375	0.744	4.250	0.463	-0.88
s2.3	Plant or equipment failure or breakdowns contribute to poor product quality and production delays	**8**	4.125	0.641	4.250	0.463	-0.13
s2.4	Plant or equipment availability and reliability contribute to poor product quality and production delays	**8**	3.875	0.641	4.125	0.354	-0.25
s2.5	Lack of skills, competencies and experience contributes to poor product quality and production delays	**8**	4.250	0.707	4.000	0.000	0.25
s2.6	Maintenance and production reworks contribute to production delays	**8**	4.250	0.463	4.125	0.354	0.13
s3.1	Product prices are reduced due to poor production quality	**8**	3.250	0.707	4.000	0.535	-0.75

		Valid N	Perception		Expectation		
			Mean-(P)	STDev	Mean-(E)	STDev	Gap
s3.2	Sale or delivery of products to customers is delayed due to plant/equipment failure or breakdown	**8**	4.000	0.926	4.000	0.535	0.00
s3.3	Company loses income or revenue due to low production volumes	**8**	4.500	0.535	3.875	0.354	0.63
s3.4	Company loses income or money due to plant/equipment failure or breakdowns	**8**	4.250	1.035	3.875	0.354	0.38
s3.5	Weekly, monthly and yearly income or revenue is within the set targets	**8**	3.000	0.756	4.000	0.535	-1.00
s3.6	Maintenance and production reworks contribute to the loss of production and revenue/income	**8**	4.000	1.069	4.375	0.518	-0.38
s4.1	There are no overdue RBI inspections for main equipment	**8**	2.875	0.641	3.875	0.354	-1.00
s4.2	There are no overdue RBI inspections for PSV's	**8**	2.875	0.875	3.750	0.463	-0.88
s4.3	There are no overdue RBI inspections for Pipeline (QP's)	**8**	2.875	0.641	3.625	0.518	-0.75
s4.4	There are no minor injuries in my area for the year 2014	**8**	2.500	0.756	3.750	0.463	-1.25
s4.5	There are no lost time injuries in my area for the year 2014	**8**	3.000	1.195	3.875	0.354	-0.88
s4.6	The level of absenteeism is acceptable in my area	**8**	2.875	0.641	3.875	0.354	-1.00
s5.1	There is no product major spillage in my area for the year 2014	**8**	3.500	0.535	4.000	0.535	-0.50
s5.2	There is no product minor spillage in my area for the year 2014	**8**	3.375	0.518	3.750	0.463	-0.38
s5.3	There are no priority 1 overdue incidents for production plant or equipment	**8**	3.250	0.707	4.000	0.535	-0.75
s6.1	There are sufficient cross trained artisans to balance work load in my area	**8**	2.750	0.463	3.750	0.463	-1.00
s6.2	There are sufficient cross trained operators to balance work load in my area	**8**	2.625	0.744	3.625	0.518	-1.00
s6.3	There are sufficient cross trained technicians to balance work load in my area	**8**	2.625	0.518	3.750	0.463	-1.13
s6.4	There are sufficient cross trained engineers to balance work load in my area	**8**	2.750	0.707	3.625	0.518	-0.88

		Valid N	Perception		Expectation		
			Mean-(P)	**STDev**	**Mean-(E)**	**STDev**	**Gap**
s6.5	There are sufficient cross trained supervisors to balance work load in my area	**8**	2.675	0.744	3.750	0.707	-1.08
s6.6	There are sufficient cross trained Inspectors to balance work load in my area	**8**	2.875	0.641	3.875	0.354	-1.00
	POI	**8**	**3.273**	**0.822**	**3.868**	**0.470**	**-0.605**

APPENDIX J: BLENDING & STORAGE MEANS, STANDARD DEVIATIONS AND GAP FOR THE PRODUCTION GROUP

		Valid N	Perception		Expectation		
			Mean-(P)	STDev	Mean-(E)	STDev	Gap
s1.1	Production plan and schedule is compiled, issued and communicated	**5**	3.800	0.837	4.200	0.447	-0.40
s1.2	Production volumes are reduced due to plant/equipment failure or breakdown	**5**	4.000	0.707	4.200	0.447	-0.20
s1.3	Daily, weekly and monthly PO is within the scheduled or planned target	**5**	3.200	0.447	4.200	0.447	-1.00
s1.4	PO is planned and scheduled as per machine, plant or equipment capacity	**5**	4.000	0.707	4.200	0.447	-0.20
s1.5	Machines, plant or equipment produce as per design capacity	**5**	3.200	0.837	4.200	0.447	-1.00
s1.6	Plant or equipment is always available after maintenance work is done on it	**5**	3.000	1.000	4.200	0.447	-1.20
s1.7	Plant or equipment is always reliable after maintenance work is done on it	**5**	3.400	1.140	4.000	0.707	-0.60
s1.8	Plant or equipment is always operable and efficient after maintenance work is done on it	**5**	3.400	1.140	4.400	0.548	-1.00
s2.1	Manufactured products are within required specification	**5**	3.800	0.837	4.400	0.548	-0.60
s2.2	Product quality is consistent	**5**	3.800	1.095	4.000	0.707	-0.20
s2.3	Plant or equipment failure or breakdowns contribute to poor product quality and production delays	**5**	4.400	0.548	4.200	0.447	0.20
s2.4	Plant or equipment availability and reliability contribute to poor product quality and production delays	**5**	4.400	0.548	4.400	0.548	0.00
s2.5	Lack of skills, competencies and experience contributes to poor product quality and production delays	**5**	4.400	0.548	4.200	0.837	0.20
s2.6	Maintenance and production reworks contribute to production delays	**5**	4.400	0.548	4.000	0.000	0.40

		Valid N	Perception		Expectation		
			Mean-(P)	STDev	Mean-(E)	STDev	Gap
s3.1	Product prices are reduced due to poor production quality	**5**	4.000	1.225	4.200	0.447	-0.20
s3.2	Sale or delivery of products to customers is delayed due to plant/equipment failure or breakdown	**5**	4.400	0.548	4.200	0.447	0.20
s3.3	Company loses income or revenue due to low production volumes	**5**	4.600	0.548	4.000	0.000	0.60
s3.4	Company loses income or money due to plant/equipment failure or breakdowns	**5**	4.200	0.837	4.000	0.000	0.20
s3.5	Weekly, monthly and yearly income or revenue is within the set targets	**5**	3.200	0.837	4.600	0.548	-1.40
s3.6	Maintenance and production reworks contribute to the loss of production and revenue/income	**5**	4.400	0.548	4.000	0.707	0.40
s4.1	There are no overdue RBI inspections for main equipment	**5**	3.000	0.707	3.600	0.548	-0.60
s4.2	There are no overdue RBI inspections for PSV's	**5**	3.000	0.707	4.000	0.707	-1.00
s4.3	There are no overdue RBI inspections for Pipeline (QP's)	**5**	2.800	0.837	4.000	0.707	-1.20
s4.4	There are no minor injuries in my area for the year 2014	**5**	3.400	0.894	3.600	0.548	-0.20
s4.5	There are no lost time injuries in my area for the year 2014	**5**	3.800	0.837	3.600	0.548	0.20
s4.6	The level of absenteeism is acceptable in my area	**5**	3.400	1.817	3.800	0.447	-0.40
s5.1	There is no product major spillage in my area for the year 2014	**5**	4.000	0.707	4.000	0.000	0.00
s5.2	There is no product minor spillage in my area for the year 2014	**5**	3.600	1.140	4.000	0.000	-0.40
s5.3	There are no priority 1 overdue incidents for production plant or equipment	**5**	3.000	0.707	4.400	0.548	-1.40
s6.1	There are sufficient cross trained artisans to balance work load in my area	**5**	3.400	0.894	4.200	0.837	-0.80
s6.2	There are sufficient cross trained operators to balance work load in my area	**5**	3.600	1.140	4.200	0.837	-0.60
s6.3	There are sufficient cross trained technicians to balance	**5**	3.400	1.140	4.200	0.837	-0.80

		Valid N	Perception		Expectation		
			Mean-(P)	**STDev**	**Mean-(E)**	**STDev**	**Gap**
	work load in my area						
s6.4	There are sufficient cross trained engineers to balance work load in my area	**5**	2.800	0.447	3.800	0.447	-1.00
s6.5	There are sufficient cross trained supervisors to balance work load in my area	**5**	3.400	1.140	4.000	0.000	-0.60
s6.6	There are sufficient cross trained Inspectors to balance work load in my area	**5**	2.800	0.447	4.000	0.707	-1.20
	POI	**5**	**3.640**	**0.830**	**4.091**	**0.483**	**-0.453**

APPENDIX K: OFFSITES & UTILITIES MEANS, STANDARD DEVIATIONS AND GAP FOR THE PRODUCTION GROUP

		Valid N	Perception		Expectation		
			Mean-(P)	STDev	Mean-(E)	STDev	Gap
s1.1	Production plan and schedule is compiled, issued and communicated	**5**	3.800	0.837	4.000	0.000	-0.20
s1.2	Production volumes are reduced due to plant/equipment failure or breakdown	**5**	3.600	0.541	3.800	0.447	-0.20
s1.3	Daily, weekly and monthly PO is within the scheduled or planned target	**5**	3.000	1.000	4.200	0.447	-1.20
s1.4	PO is planned and scheduled as per machine, plant or equipment capacity	**5**	3.200	0.447	3.800	0.447	-0.60
s1.5	Machines, plant or equipment produce as per design capacity	**5**	2.800	0.837	3.600	0.548	-0.80
s1.6	Plant or equipment is always available after maintenance work is done on it	**5**	2.800	1.095	3.800	0.837	-1.00
s1.7	Plant or equipment is always reliable after maintenance work is done on it	**5**	2.800	0.837	3.400	0.548	-0.60
s1.8	Plant or equipment is always operable and efficient after maintenance work is done on it	**5**	2.800	0.837	4.200	0.447	-1.40
s2.1	Manufactured products are within required specification	**5**	4.000	0.707	4.200	0.837	-0.20
s2.2	Product quality is consistent	**5**	3.400	0.894	3.200	0.447	0.20
s2.3	Plant or equipment failure or breakdowns contribute to poor product quality and production delays	**5**	3.800	0.837	4.000	0.707	-0.20
s2.4	Plant or equipment availability and reliability contribute to poor product quality and production delays	**5**	3.200	0.837	4.000	0.707	-0.80
s2.5	Lack of skills, competencies and experience contributes to poor product quality and production delays	**5**	3.400	1.517	3.600	0.548	-0.20
s2.6	Maintenance and production reworks contribute to production delays	**5**	4.200	0.837	4.000	0.707	0.20

		Valid N	Perception		Expectation		
			Mean-(P)	STDev	Mean-(E)	STDev	Gap
s3.1	Product prices are reduced due to poor production quality	**5**	3.400	0.894	4.000	0.707	-0.60
s3.2	Sale or delivery of products to customers is delayed due to plant/equipment failure or breakdown	**5**	3.800	0.837	3.800	0.447	0.00
s3.3	Company loses income or revenue due to low production volumes	**5**	4.200	0.837	3.800	0.447	0.40
s3.4	Company loses income or money due to plant/equipment failure or breakdowns	**5**	4.000	0.707	4.200	0.447	-0.20
s3.5	Weekly, monthly and yearly income or revenue is within the set targets	**5**	3.400	0.894	3.800	0.447	-0.40
s3.6	Maintenance and production reworks contribute to the loss of production and revenue/income	**5**	3.800	1.095	4.000	0.000	-0.20
s4.1	There are no overdue RBI inspections for main equipment	**5**	1.800	1.304	3.400	0.894	-1.60
s4.2	There are no overdue RBI inspections for PSV's	**5**	2.000	1.225	3.400	0.894	-1.40
s4.3	There are no overdue RBI inspections for Pipeline (QP's)	**5**	2.200	1.304	3.200	0.447	-1.00
s4.4	There are no minor injuries in my area for the year 2014	**5**	2.800	0.837	3.800	0.837	-1.00
s4.5	There are no lost time injuries in my area for the year 2014	**5**	4.200	1.095	3.800	0.447	0.40
s4.6	The level of absenteeism is acceptable in my area	**5**	2.800	1.304	3.800	0.447	-1.00
s5.1	There is no product major spillage in my area for the year 2014	**5**	2.800	1.483	3.800	0.447	-1.00
s5.2	There is no product minor spillage in my area for the year 2014	**5**	2.200	1.304	3.400	0.548	-1.20
s5.3	There are no priority 1 overdue incidents for production plant or equipment	**5**	3.400	0.548	3.800	0.447	-0.40
s6.1	There are sufficient cross trained artisans to balance work load in my area	**5**	2.000	0.707	3.200	0.447	-1.20
s6.2	There are sufficient cross trained operators to balance work load in my area	**5**	2.000	0.707	3.400	0.548	-1.40
s6.3	There are sufficient cross trained technicians to balance work load in my area	**5**	2.600	0.894	3.800	0.447	-1.20

		Valid N	Perception		Expectation		
			Mean-(P)	**STDev**	**Mean-(E)**	**STDev**	**Gap**
s6.4	There are sufficient cross trained engineers to balance work load in my area	**5**	3.400	0.894	4.000	0.000	-0.60
s6.5	There are sufficient cross trained supervisors to balance work load in my area	**5**	2.600	0.548	3.200	0.447	-0.60
s6.6	There are sufficient cross trained Inspectors to balance work load in my area	**5**	2.400	0.548	3.600	0.548	-1.20
	POI	**5**	**3.103**	**0.915**	**3.743**	**0.515**	**-0.653**

APPENDIX L: PRODUCTION OUTPUT AND PROFITABILITY – PERCEPTION % RESPONSES

		Total	1	2	3	4	5
1.0	**PO Perspective**						
s1.1	Production plan and schedule is compiled, issued and communicated	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s1.2	Production volumes are reduced due to plant/equipment failure or breakdown	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s1.3	Daily, weekly and monthly PO is within the scheduled or planned target	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s1.4	PO is planned and scheduled as per machine, plant or equipment capacity	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s1.5	Machines, plant or equipment produce as per design capacity	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s1.6	Plant or equipment is always available after maintenance work is done on it	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s1.7	Plant or equipment is always reliable after maintenance work is done on it	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s1.8	Plant or equipment is always operable and efficient after maintenance work is done on it	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
2.0	**Quality Perspective**						

		Total	1	2	3	4	5
s2.1	Manufactured products are within required specification	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s2.2	Product quality is consistent	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s2.3	Plant or equipment failure or breakdowns contribute to poor product quality and production delays	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s2.4	Plant or equipment availability and reliability contribute to poor product quality and production delays	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s2.5	Lack of skills, competencies and experience contributes to poor product quality and production delays	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s2.6	Maintenance and production reworks contribute to production delays	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
3.0	**Cost Perspective**						
s3.1	Product prices are reduced due to poor production quality	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s3.2	Sale or delivery of products to customers is delayed due to plant/equipment failure or breakdown	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s3.3	Company loses income or revenue due to low production volumes	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%

		Total	1	2	3	4	5
s3.4	Company loses income or money due to plant/equipment failure or breakdowns	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s3.5	Weekly, monthly and yearly income or revenue is within the set targets	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s3.6	Maintenance and production reworks contribute to the loss of production and revenue/income	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
4.0	**Safety Perspective**						
s4.1	There are no overdue RBI inspections for main equipment	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s4.2	There are no overdue RBI inspections for PSV's	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s4.3	There are no overdue RBI inspections for Pipeline (QP's)	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s4.4	There are no minor injuries in my area for the year 2014	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s4.5	There are no lost time injuries in my area for the year 2014	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s4.6	The level of absenteeism is acceptable in my area	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
5.0	**Environmental Perspective**						

		Total	1	2	3	4	5
s5.1	There is no product major spillage in my area for the year 2014	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s5.2	There is no product minor spillage in my area for the year 2014	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s5.3	There are no priority 1 overdue incidents for production plant or equipment	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
6.0	**Learning and Growing Perspective**						
s6.1	There are sufficient cross trained artisans to balance work load in my area	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s6,2	There are sufficient cross trained operators to balance work load in my area	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s6.3	There are sufficient cross trained technicians to balance work load in my area	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s6.4	There are sufficient cross trained engineers to balance work load in my area	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s6.5	There are sufficient cross trained supervisors to balance work load in my area	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s6.6	There are sufficient cross trained Inspectors to balance work load in my area	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%

APPENDIX M: PRODUCTION OUTPUT AND PROFITABILITY EXPECTATION PERCENTAGE RESPONSES

		Total	1	2	3	4	5
1.0	**PO Perspective**						
s1.1	Production plan and schedule is compiled, issued and communicated	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s1.2	Production volumes are reduced due to plant/equipment failure or breakdown	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s1.3	Daily, weekly and monthly PO is within the scheduled or planned target	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s1.4	PO is planned and scheduled as per machine, plant or equipment capacity	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s1.5	Machines, plant or equipment produce as per design capacity	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s1.6	Plant or equipment is always available after maintenance work is done on it	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s1.7	Plant or equipment is always reliable after maintenance work is done on it	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s1.8	Plant or equipment is always operable and efficient after maintenance work is done on it	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
2.0	**Quality Perspective**						

		Total	1	2	3	4	5
s2.1	Manufactured products are within required specification	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s2.2	Product quality is consistent	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s2.3	Plant or equipment failure or breakdowns contribute to poor product quality and production delays	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s2.4	Plant or equipment availability and reliability contribute to poor product quality and production delays	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s2.5	Lack of skills, competencies and experience contributes to poor product quality and production delays	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s2.6	Maintenance and production reworks contribute to production delays	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
3.0	**Cost Perspective**						
s3.1	Product prices are reduced due to poor production quality	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s3.2	Sale or delivery of products to customers is delayed due to plant/equipment failure or breakdown	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s3.3	Company loses income or revenue due to low production volumes	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s3.4	Company loses income or money due to plant/equipment failure or breakdowns	**38**	38	38	38	38	38

		Total	1	2	3	4	5
			100%	100%	100%	100%	100%
s3.5	Weekly, monthly and yearly income or revenue is within the set targets	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s3.6	Maintenance and production reworks contribute to the loss of production and revenue/income	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
4.0	**Safety Perspective**						
s4.1	There are no overdue RBI inspections for main equipment	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s4.2	There are no overdue RBI inspections for PSV's	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s4.3	There are no overdue RBI inspections for Pipeline (QP's)	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s4.4	There are no minor injuries in my area for the year 2014	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s4.5	There are no lost time injuries in my area for the year 2014	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s4.6	The level of absenteeism is acceptable in my area	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
5.0	**Environmental Perspective**						
s5.1	There is no product major spillage in my area for the year 2014	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%

		Total	1	2	3	4	5
s5.2	There is no product minor spillage in my area for the year 2014	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s5.3	There are no priority 1 overdue incidents for production plant or equipment	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
6.0	**Learning and Growing Perspective**						
s6.1	There are sufficient cross trained artisans to balance work load in my area	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s6,2	There are sufficient cross trained operators to balance work load in my area	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s6.3	There are sufficient cross trained technicians to balance work load in my area	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s6.4	There are sufficient cross trained engineers to balance work load in my area	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s6.5	There are sufficient cross trained supervisors to balance work load in my area	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%
s6.6	There are sufficient cross trained Inspectors to balance work load in my area	**38**	38	38	38	38	38
			100%	100%	100%	100%	100%

APPENDIX N: MMS PERCENTAGE PERCEPTION RESPONSE

		Total	1	2	3	4	5
1.0	**Organisational structure and size**						
s1.1	Decisions can be made and carried out at the lowest appropriate level	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s1.2	Supervisors are not so overloaded with administrative or other duties that performance of their direct supervisory duties is hampered	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s1.3	There are sufficient cross trained artisans, technicians and engineers to provide quality maintenance management service	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s1.4	Communication channels and procedures are designed for clear and quick transmission of information	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s1.5	Relationships with staff departments such as Procurement, stores, finance and others are clearly defined	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
2.0	**Computer information and support**						
s2.1	The MMS is computerised	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s2.2	The right maintenance information is available to all levels of the organisation	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s2.3	Information is complete and reliable	**56**	56	56	56	56	56

		Total	1	2	3	4	5
			100%	100%	100%	100%	100%
s2.4	Monthly maintenance cost reports are compiled and readily available	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s2.5	Information, data and history is accessible, retrievable and user friendly	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
3.0	**Work/Job Planning**						
s3.1	Weekly and monthly look ahead plans are compiled, approved and communicated	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s3.2	Policy specifies how detailed planning of selected maintenance work is done and a target has be established	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s3.3	The concept of maintenance planning is fully accepted by maintenance supervisors	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s3.4	Planning procedures are well documented	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s3.5	All shutdown work is pre-planned	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s3.6	Short and long term outage plans are compiled, approved and communicated	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
4.0	**Maintenance work measurement**						
s4.1	Weekly maintenance Key Performance indicators (KPIs) are compiled, issued and communicated	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%

		Total	1	2	3	4	5
s4.2	Monthly maintenance KPIs are compiled, issued and communicated	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s4.3	Visual planning boards are updated weekly	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s4.4	KPI trends are discussed bi-monthly, corrective and preventive measures devised and taken	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s4.5	Capacity plans are compiled and issued weekly	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s4.6	Maintenance KPIs add value to improvement of MMS	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
5.0	**Material support and control**						
s5.1	Minimum and maximum Inventory/stock levels are defined or set	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s5.2	Stock taking/cycle counting is used to preserve reliability of stock/inventory records	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s5.3	An intelligent part numbering system is utilised	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s5.4	Usage records are employed to determine stock levels order points and order quantities	**56**	56	56	56	56	56
s5.5	Maintenance, Procurement, Finance and Stores, work together to assure availability of necessary parts; elimination of obsolete parts, adjustment of stock levels	**56**	56	56	56	56	56

		Total	1	2	3	4	5
			100%	100%	100%	100%	100%
6.0	**Maintenance scheduling and coordination**						
s6.1	The system of work prioritisation effectively distinguish between legitimate rush jobs and those which can be planned	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s6.2	Scheduled jobs start and completion dates, resource allocation and duration are published, distributed and communicated	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s6.3	Schedule compliance substantiated by KPI report is high	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s6.4	Planned and scheduled work is completed on time and substantiated by KPI report	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s6.5	Procedure for requesting, coordinating and controlling support services such as scaffolding; HP cleaning; rigging; cranes and workshops is effective	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%

APPENDIX O: MMS PERCENTAGE EXPECTATION RESPONSE

		Total	1	2	3	4	5
1.0	**Organisational structure and size**						
s1.1	Decisions can be made and carried out at the lowest appropriate level	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s1.2	Supervisors are not so overloaded with administrative or other duties that performance of their direct supervisory duties is hampered	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s1.3	There are sufficient cross trained artisans, technicians and engineers to provide quality maintenance management service	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s1.4	Communication channels and procedures are designed for clear and quick transmission of information	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s1.5	Relationships with staff departments such as Procurement, stores, finance and others are clearly defined	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
2.0	**Computer information and support**						
s2.1	The MMS is computerised	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s2.2	The right maintenance information is available to all levels of the organisation	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s2.3	Information is complete and reliable	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%

		Total	1	2	3	4	5
s2.4	Monthly maintenance cost reports are compiled and readily available	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s2.5	Information, data and history is accessible, retrievable and user friendly	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
3.0	**Work/Job Planning**						
s3.1	Weekly and monthly look ahead plans are compiled, approved and communicated	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s3.2	Policy specifies how detailed planning of selected maintenance work is done and a target has be established	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s3.3	The concept of maintenance planning is fully accepted by maintenance supervisors	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s3.4	Planning procedures are well documented	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s3.5	All shutdown work is pre-planned	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s3.6	Short and long term outage plans are compiled, approved and communicated	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
4.0	**Maintenance work measurement**						
s4.1	Weekly maintenance Key Performance indicators (KPIs) are compiled, issued and communicated	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s4.2	Monthly maintenance KPIs are compiled, issued and communicated	**56**	56	56	56	56	56

		Total	1	2	3	4	5
			100%	100%	100%	100%	100%
s4.3	Visual planning boards are updated weekly	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s4.4	KPI trends are discussed bi-monthly, corrective and preventive measures devised and taken	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s4.5	Capacity plans are compiled and issued weekly	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s4.6	Maintenance KPIs add value to improvement of MMS	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
5.0	**Material support and control**						
s5.1	Minimum and maximum Inventory/stock levels are defined or set	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s5.2	Stock taking/cycle counting is used to preserve reliability of stock/inventory records	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s5.3	An intelligent part numbering system is utilised	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s5.4	Usage records are employed to determine stock levels order points and order quantities	**56**	56	56	56	56	56
s5.5	Maintenance, Procurement, Finance and Stores, work together to assure availability of necessary parts; elimination of obsolete parts, adjustment of stock levels	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%

		Total	1	2	3	4	5
6.0	**Maintenance scheduling and coordination**						
s6.1	The system of work prioritisation effectively distinguish between legitimate rush jobs and those which can be planned	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s6.2	Scheduled jobs start and completion dates, resource allocation and duration are published, distributed and communicated	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s6.3	Schedule compliance substantiated by KPI report is high	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s6.4	Planned and scheduled work is completed on time and substantiated by KPI report	**56**	56	56	56	56	56
			100%	100%	100%	100%	100%
s6.5	Procedure for requesting, coordinating and controlling support services such as scaffolding; HP cleaning; rigging; cranes and workshops is effective	**56**	56	56	56	56	56

APPENDIX P: AGS STANDARD DEVIATIONS, MEANS AND GAP FOR MMS

			Perception		Expectation		
		Valid N	**Mean-(P)**	**STDev-(P)**	**Mean-(E)**	**STDev-(E)**	**Gap**
s1.1	Decisions can be made and carried out at the lowest appropriate level	**8**	3.000	1.414	4.375	0.518	-1.38
s1.2	Supervisors are not so overloaded with administrative or other duties that performance of their direct supervisory duties is hampered	**8**	2.375	0.744	4.250	0.463	-1.88
s1.3	There are sufficient cross trained artisans, technicians and engineers to provide quality maintenance management service	**8**	2.250	1.035	4.375	0.518	-2.13
s1.4	Communication channels and procedures are designed for clear and quick transmission of information	**8**	3.250	1.035	4.375	0.518	-1.13
s1.5	Relationships with staff departments such as Procurement, stores, finance and others are clearly defined	**8**	2.875	0.835	4.250	0.463	-1.38
s2.1	The MMS is computerised	**8**	4.000	1.069	4.250	0.707	-0.25
s2.2	The right maintenance information is available to all levels of the organisation	**8**	2.750	1.886	3.875	0.354	-1.13
s2.3	Information is complete and reliable	**8**	2.875	0.991	4.000	0.535	-1.13
s2.4	Monthly maintenance cost reports are compiled and readily available	**8**	3.500	0.926	4.375	0.744	-0.88
s2.5	Information, data and history is accessible, retrievable and user friendly	**8**	3.750	0.686	4.375	0.744	-0.63
s3.1	Weekly and monthly look ahead plans are compiled, approved and communicated	**8**	3.000	0.926	3.375	0.518	-0.38
s3.2	Policy specifies how detailed planning of selected maintenance work is done and a target has be established	**8**	3.625	0.916	3.375	0.518	0.25
s3.3	The concept of maintenance planning is fully accepted by maintenance supervisors	**8**	3.000	0.926	3.375	0.518	-0.38
s3.4	Planning procedures are well documented	**8**	3.375	0.518	3.875	0.641	-0.50

			Perception		Expectation		
		Valid N	**Mean-(P)**	**STDev-(P)**	**Mean-(E)**	**STDev-(E)**	**Gap**
s3.5	All shutdown work is pre-planned	**8**	3.375	1.302	4.125	0.835	-0.75
s3.6	Short and long term outage plans are compiled, approved and communicated	**8**	3.875	0.641	4.500	0.756	-0.63
s4.1	Weekly maintenance Key Performance indicators (KPIs) are compiled, issued and communicated	**8**	3.125	0.991	3.625	1.188	-0.50
s4.2	Monthly maintenance KPIs are compiled, issued and communicated	**8**	3.125	0.991	3.250	1.165	-0.13
s4.3	Visual planning boards are updated weekly	**8**	2.500	0.926	3.125	0.835	-0.63
s4.4	KPI trends are discussed bi-monthly, corrective and preventive measures devised and taken	**8**	2.875	1.126	2.875	0.991	0.00
s4.5	Capacity plans are compiled and issued weekly	**8**	3.125	1.126	3.625	0.744	-0.50
s4.6	Maintenance KPIs add value to improvement of MMS	**8**	2.625	0.916	3.125	1.246	-0.50
s5.1	Minimum and maximum Inventory/stock levels are defined or set	**8**	3.500	1.309	4.125	0.641	-0.63
s5.2	Stock taking/cycle counting is used to preserve reliability of stock/inventory records	**8**	3.625	1.188	4.125	0.463	-0.50
s5.3	An intelligent part numbering system is utilised	**8**	2.875	1.126	4.000	0.535	-1.13
s5.4	Usage records are employed to determine stock levels order points and order quantities	**8**	2.875	0.835	4.000	0.535	-1.13
s5.5	Maintenance, Procurement, Finance and Stores, work together to assure availability of necessary parts; elimination of obsolete parts, adjustment of stock levels	**8**	2.750	1.282	4.125	0.354	-1.38
s6.1	The system of work prioritisation effectively distinguish between legitimate rush jobs and those which can be planned	**8**	3.250	1.356	3.875	0.641	-0.63
s6.2	Scheduled jobs start and completion dates, resource allocation and duration are published, distributed and communicated	**8**	3.000	1.069	3.875	0.641	-0.88

			Perception		Expectation		
		Valid N	**Mean-(P)**	**STDev-(P)**	**Mean-(E)**	**STDev-(E)**	**Gap**
s6.3	Schedule compliance substantiated by KPI report is high	**8**	2.875	0.991	4.000	0.926	-1.13
s6.4	Planned and scheduled work is completed on time and substantiated by KPI report	**8**	2.625	1.302	3.875	0.641	-1.25
s6.5	Procedure for requesting, coordinating and controlling support services such as scaffolding; HP cleaning; rigging; cranes and workshops is effective	**8**	2.750	1.488	4.125	0.835	-1.38
	MMSI	**8**	**3.074**	**1.059**	**3.902**	**0.679**	**-0.828**

APPENDIX Q: RFM STANDARD DEVIATIONS, MEANS AND GAP FOR MMS

			Perception		Expectation		
		Valid N	Mean (P)	STDev	Mean (E)	STDev	Gap
s1.1	Decisions can be made and carried out at the lowest appropriate level	**8**	2.875	0.991	3.750	0.463	-0.88
s1.2	Supervisors are not so overloaded with administrative or other duties that performance of their direct supervisory duties is hampered	**8**	2.750	1.282	3.750	0.707	-1.00
s1.3	There are sufficient cross trained artisans, technicians and engineers to provide quality maintenance management service	**8**	3.125	1.126	3.750	0.707	-0.63
s1.4	Communication channels and procedures are designed for clear and quick transmission of information	**8**	2.875	0.641	3.875	0.641	-1.00
s1.5	Relationships with staff departments such as Procurement, stores, finance and others are clearly defined	**8**	2.625	1.061	3.625	0.744	-1.00
s2.1	The MMS is computerised	**8**	3.750	0.707	4.250	0.463	-0.50
s2.2	The right maintenance information is available to all levels of the organisation	**8**	3.375	0.744	4.125	0.641	-0.75
s2.3	Information is complete and reliable	**8**	2.875	0.641	3.875	0.641	-1.00
s2.4	Monthly maintenance cost reports are compiled and readily available	**8**	3.000	0.756	3.750	0.707	-0.75
s2.5	Information, data and history is accessible, retrievable and user friendly	**8**	2.625	1.061	3.375	0.518	-0.75
s3.1	Weekly and monthly look ahead plans are compiled, approved and communicated	**8**	3.500	0.756	4.500	0.756	-1.00
s3.2	Policy specifies how detailed planning of selected maintenance work is done and a target has be established	**8**	3.500	0.926	4.375	0.744	-0.88
s3.3	The concept of maintenance planning is fully accepted by maintenance supervisors	**8**	3.375	0.744	4.250	0.707	-0.88
s3.4	Planning procedures are well documented	**8**	3.125	0.991	4.125	0.991	-1.00

			Perception		Expectation		
		Valid N	Mean (P)	STDev	Mean (E)	STDev	Gap
s3.5	All shutdown work is pre-planned	**8**	3.625	0.518	4.500	0.535	-0.88
s3.6	Short and long term outage plans are compiled, approved and communicated	**8**	3.500	0.535	4.500	0.535	-1.00
s4.1	Weekly maintenance Key Performance indicators (KPIs) are compiled, issued and communicated	**8**	2.875	1.356	4.250	0.463	-1.38
s4.2	Monthly maintenance KPIs are compiled, issued and communicated	**8**	3.125	1.246	4.375	0.518	-1.25
s4.3	Visual planning boards are updated weekly	**8**	2.750	1.389	3.875	0.835	-1.13
s4.4	KPI trends are discussed bi-monthly, corrective and preventive measures devised and taken	**8**	3.125	0.991	4.000	0.756	-0.88
s4.5	Capacity plans are compiled and issued weekly	**8**	3.000	1.069	4.250	0.886	-1.25
s4.6	Maintenance KPIs add value to improvement of MMS	**8**	3.000	0.926	4.375	0.518	-1.38
s5.1	Minimum and maximum Inventory/stock levels are defined or set	**8**	3.375	0.518	4.375	0.518	-1.00
s5.2	Stock taking/cycle counting is used to preserve reliability of stock/inventory records	**8**	3.500	0.756	4.375	0.518	-0.88
s5.3	An intelligent part numbering system is utilised	**8**	3.250	1.165	4.375	0.518	-1.13
s5.4	Usage records are employed to determine stock levels order points and order quantities	**8**	3.000	0.926	4.125	0.641	-1.13
s5.5	Maintenance, Procurement, Finance and Stores, work together to assure availability of necessary parts; elimination of obsolete parts, adjustment of stock levels	**8**	2.750	0.886	3.625	0.916	-0.88
s6.1	The system of work prioritisation effectively distinguish between legitimate rush jobs and those which can be planned	**8**	2.875	0.991	4.000	0.756	-1.13
s6.2	Scheduled jobs start and completion dates, resource allocation and duration are published, distributed and communicated	**8**	2.875	0.835	4.250	0.707	-1.38
s6.3	Schedule compliance substantiated by KPI report is high	**8**	3.000	0.756	4.250	0.463	-1.25

			Perception		Expectation		
		Valid N	Mean (P)	STDev	Mean (E)	STDev	Gap
s6.4	Planned and scheduled work is completed on time and substantiated by KPI report	**8**	3.000	0.756	4.375	0.518	-1.38
s6.5	Procedure for requesting, coordinating and controlling support services such as scaffolding; HP cleaning; rigging; cranes and workshops is effective	**8**	3.000	0.756	4.375	0.518	-1.38
	MMSI	**8**	**3.094**	**0.900**	**4.113**	**0.642**	**-1.020**

APPENDIX R: SNT STANDARD DEVIATIONS, MEANS AND GAP FOR MMS

			Perception		Expectation		
		Valid N	**Mean-(P)**	**STDev**	**Mean-(E)**	**STDev**	**Gap**
s1.1	Decisions can be made and carried out at the lowest appropriate level	**9**	2.222	0.833	3.778	0.667	-1.56
s1.2	Supervisors are not so overloaded with administrative or other duties that performance of their direct supervisory duties is hampered	**9**	2.444	0.882	4.222	0.441	-1.78
s1.3	There are sufficient cross trained artisans, technicians and engineers to provide quality maintenance management service	**9**	1.889	0.928	3.556	0.726	-1.67
s1.4	Communication channels and procedures are designed for clear and quick transmission of information	**9**	3.000	0.866	4.111	0.333	-1.11
s1.5	Relationships with staff departments such as Procurement, stores, finance and others are clearly defined	**9**	2.222	0.972	3.667	0.707	-1.45
s2.1	The MMS is computerised	**9**	4.000	0.500	5.000	0.000	-1.00
s2.2	The right maintenance information is available to all levels of the organisation	**9**	2.667	1.225	4.556	0.527	-1.89
s2.3	Information is complete and reliable	**9**	2.667	0.707	4.556	0.527	-1.89
s2.4	Monthly maintenance cost reports are compiled and readily available	**9**	3.444	1.014	4.333	0.707	-0.89
s2.5	Information, data and history is accessible, retrievable and user friendly	**9**	3.111	0.782	4.333	0.707	-1.22
s3.1	Weekly and monthly look ahead plans are compiled, approved and communicated	**9**	4.000	0.707	4.778	0.441	-0.78
s3.2	Policy specifies how detailed planning of selected maintenance work is done and a target has be established	**9**	3.667	1.118	4.556	0.726	-0.89
s3.3	The concept of maintenance planning is fully accepted by maintenance supervisors	**9**	3.444	1.014	4.444	0.726	-1.00
s3.4	Planning procedures are well documented	**9**	3.889	1.266	4.444	0.726	-0.56
s3.5	All shutdown work is pre-planned	**9**	4.111	1.054	4.778	0.667	-0.67

			Perception		Expectation		
		Valid N	Mean-(P)	STDev	Mean-(E)	STDev	Gap
s3.6	Short and long term outage plans are compiled, approved and communicated	**9**	4.111	1.054	4.889	0.333	-0.78
s4.1	Weekly maintenance Key Performance indicators (KPIs) are compiled, issued and communicated	**9**	3.778	0.833	4.556	0.527	-0.78
s4.2	Monthly maintenance KPIs are compiled, issued and communicated	**9**	3.889	0.601	4.667	0.500	-0.78
s4.3	Visual planning boards are updated weekly	**9**	3.444	0.882	4.667	0.707	-1.22
s4.4	KPI trends are discussed bi-monthly, corrective and preventive measures devised and taken	**9**	3.667	0.707	4.556	0.527	-0.89
s4.5	Capacity plans are compiled and issued weekly	**9**	3.222	0.833	4.444	0.726	-1.22
s4.6	Maintenance KPIs add value to improvement of MMS	**9**	3.556	0.882	4.333	0.707	-0.78
s5.1	Minimum and maximum Inventory/stock levels are defined or set	**9**	3.778	0.833	4.556	0.527	-0.78
s5.2	Stock taking/cycle counting is used to preserve reliability of stock/inventory records	**9**	3.889	0.601	4.778	0.441	-0.89
s5.3	An intelligent part numbering system is utilised	**9**	3.444	0.882	4.444	0.882	-1.00
s5.4	Usage records are employed to determine stock levels order points and order quantities	**9**	3.667	0.707	4.667	0.500	-1.00
s5.5	Maintenance, Procurement, Finance and Stores, work together to assure availability of necessary parts; elimination of obsolete parts, adjustment of stock levels	**9**	3.222	0.833	4.222	0.833	-1.00
s6.1	The system of work prioritisation effectively distinguish between legitimate rush jobs and those which can be planned	**9**	3.222	0.972	4.111	0.928	-0.89
s6.2	Scheduled jobs start and completion dates, resource allocation and duration are published, distributed and communicated	**9**	3.556	0.726	4.556	0.726	-1.00
s6.3	Schedule compliance substantiated by KPI report is high	**9**	3.222	0.667	4.111	0.601	-0.89
s6.4	Planned and scheduled work is completed on time and substantiated by KPI report	**9**	3.333	0.707	4.333	0.707	-1.00

			Perception		Expectation		
		Valid N	**Mean-(P)**	**STDev**	**Mean-(E)**	**STDev**	**Gap**
s6.5	Procedure for requesting, coordinating and controlling support services such as scaffolding; HP cleaning; rigging; cranes and workshops is effective	**9**	3.111	0.782	4.444	0.726	-1.33
	MMSI	**9**	**3.340**	**0.855**	**4.420**	**0.610**	**-1.080**

APPENDIX S: REF STANDARD DEVIATIONS, MEANS AND GAP FOR MMS

			Perception		Expectation		
		Valid N	**Mean-(P)**	**STDev**	**Mean-(E)**	**STDev**	**Gap**
s1.1	Decisions can be made and carried out at the lowest appropriate level	**13**	3.077	0.954	4.154	0.801	-1.08
s1.2	Supervisors are not so overloaded with administrative or other duties that performance of their direct supervisory duties is hampered	**13**	2.462	0.967	4.077	0.494	-1.62
s1.3	There are sufficient cross trained artisans, technicians and engineers to provide quality maintenance management service	**13**	3.000	1.155	4.231	0.832	-1.23
s1.4	Communication channels and procedures are designed for clear and quick transmission of information	**13**	3.615	0.870	4.692	0.480	-1.08
s1.5	Relationships with staff departments such as Procurement, stores, finance and others are clearly defined	**13**	3.154	0.899	4.462	0.660	-1.31
s2.1	The MMS is computerised	**13**	3.846	0.801	4.692	0.480	-0.85
s2.2	The right maintenance information is available to all levels of the organisation	**13**	3.077	0.862	4.462	0.660	-1.39
s2.3	Information is complete and reliable	**13**	3.077	0.862	4.385	0.506	-1.31
s2.4	Monthly maintenance cost reports are compiled and readily available	**13**	3.231	0.725	4.462	0.519	-1.23
s2.5	Information, data and history is accessible, retrievable and user friendly	**13**	3.000	0.816	4.154	0.689	-1.15
s3.1	Weekly and monthly look ahead plans are compiled, approved and communicated	**13**	3.846	0.689	4.692	0.480	-0.85
s3.2	Policy specifies how detailed planning of selected maintenance work is done and a target has be established	**13**	3.538	0.877	4.538	0.660	-1.00
s3.3	The concept of maintenance planning is fully accepted by maintenance supervisors	**13**	3.538	0.660	4.462	0.519	-0.92
s3.4	Planning procedures are well documented	**13**	3.462	0.967	4.308	0.751	-0.85
s3.5	All shutdown work is pre-planned	**13**	3.923	0.641	4.692	0.480	-0.77
s3.6	Short and long term outage plans are compiled, approved and communicated	**13**	3.692	0.855	4.462	0.776	-0.77
s4.1	Weekly maintenance Key Performance indicators (KPIs) are compiled, issued and communicated	**13**	3.538	0.236	4.462	0.660	-0.92

			Perception		Expectation		
		Valid N	**Mean-(P)**	**STDev**	**Mean-(E)**	**STDev**	**Gap**
s4.2	Monthly maintenance KPIs are compiled, issued and communicated	**13**	3.692	0.480	4.692	0.480	-1.00
s4.3	Visual planning boards are updated weekly	**13**	3.154	0.899	4.154	0.889	-1.00
s4.4	KPI trends are discussed bi-monthly, corrective and preventive measures devised and taken	**13**	3.462	0.519	4.462	0.519	-1.00
s4.5	Capacity plans are compiled and issued weekly	**13**	3.923	0.760	4.769	0.439	-0.85
s4.6	Maintenance KPIs add value to improvement of MMS	**13**	3.615	0.768	5.538	0.519	-1.92
s5.1	Minimum and maximum Inventory/stock levels are defined or set	**13**	3.615	0.506	4.615	0.506	-1.00
s5.2	Stock taking/cycle counting is used to preserve reliability of stock/inventory records	**13**	3.692	0.630	4.692	0.480	-1.00
s5.3	An intelligent part numbering system is utilised	**13**	3.308	0.751	4.308	0.751	-1.00
s5.4	Usage records are employed to determine stock levels order points and order quantities	**13**	3.308	0.947	4.231	0.832	-0.92
s5.5	Maintenance, Procurement, Finance and Stores, work together to assure availability of necessary parts; elimination of obsolete parts, adjustment of stock levels	**13**	3.231	0.927	4.154	0.801	-0.92
s6.1	The system of work prioritisation effectively distinguish between legitimate rush jobs and those which can be planned	**13**	3.000	1.000	4.077	0.954	-1.08
s6.2	Scheduled jobs start and completion dates, resource allocation and duration are published, distributed and communicated	**13**	3.538	0.967	4.385	0.768	-0.85
s6.3	Schedule compliance substantiated by KPI report is high	**13**	3.077	0.641	4.077	0.641	-1.00
s6.4	Planned and scheduled work is completed on time and substantiated by KPI report	**13**	3.077	0.641	4.231	0.439	-1.15
s6.5	Procedure for requesting, coordinating and controlling support services such as scaffolding; HP cleaning; rigging; cranes and workshops is effective	**13**	3.000	0.913	4.385	0.650	-1.39
	MSSI	**13**	**3.368**	**0.787**	**4.442**	**0.629**	**-1.075**

APPENDIX T: B&S STANDARD DEVIATIONS, MEANS AND GAP FOR MMS

			Perception		Expectation		
		Valid N	**Mean-(P)**	**STDev**	**Mean-(E)**	**STDev**	**Gap**
s1.1	Decisions can be made and carried out at the lowest appropriate level	**8**	2.750	0.886	4.000	0.535	-1.25
s1.2	Supervisors are not so overloaded with administrative or other duties that performance of their direct supervisory duties is hampered	**8**	3.375	1.408	4.375	0.744	-1.00
s1.3	There are sufficient cross trained artisans, technicians and engineers to provide quality maintenance management service	**8**	2.875	0.641	4.000	0.535	-1.13
s1.4	Communication channels and procedures are designed for clear and quick transmission of information	**8**	3.500	0.926	4.500	0.535	-1.00
s1.5	Relationships with staff departments such as Procurement, stores, finance and others are clearly defined	**8**	2.875	0.835	4.000	0.535	-1.13
s2.1	The MMS is computerised	**8**	3.250	1.282	4.000	0.926	-0.75
s2.2	The right maintenance information is available to all levels of the organisation	**8**	2.750	1.282	4.375	0.518	-1.63
s2.3	Information is complete and reliable	**8**	2.750	1.282	4.125	0.835	-1.38
s2.4	Monthly maintenance cost reports are compiled and readily available	**8**	3.000	0.926	4.250	0.463	-1.25
s2.5	Information, data and history is accessible, retrievable and user friendly	**8**	3.000	1.069	4.250	0.707	-1.25
s3.1	Weekly and monthly look ahead plans are compiled, approved and communicated	**8**	3.375	0.916	4.250	0.707	-0.88
s3.2	Policy specifies how detailed planning of selected maintenance work is done and a target has be established	**8**	3.500	1.414	4.375	0.916	-0.88
s3.3	The concept of maintenance planning is fully accepted by maintenance supervisors	**8**	3.125	1.246	4.250	0.707	-1.13

			Perception		Expectation		
		Valid N	**Mean-(P)**	**STDev**	**Mean-(E)**	**STDev**	**Gap**
s3.4	Planning procedures are well documented	**8**	3.500	0.756	4.500	0.756	-1.00
s3.5	All shutdown work is pre-planned	**8**	3.250	1.488	4.250	0.886	-1.00
s3.6	Short and long term outage plans are compiled, approved and communicated	**8**	3.875	1.126	4.625	0.518	-0.75
s4.1	Weekly maintenance Key Performance indicators (KPIs) are compiled, issued and communicated	**8**	3.375	1.188	4.500	0.535	-1.13
s4.2	Monthly maintenance KPIs are compiled, issued and communicated	**8**	3.500	1.061	4.250	0.707	-0.75
s4.3	Visual planning boards are updated weekly	**8**	3.125	0.991	4.250	0.707	-1.13
s4.4	KPI trends are discussed bi-monthly, corrective and preventive measures devised and taken	**8**	3.625	0.744	4.500	0.535	-0.88
s4.5	Capacity plans are compiled and issued weekly	**8**	3.250	0.707	4.250	0.707	-1.00
s4.6	Maintenance KPIs add value to improvement of MMS	**8**	3.250	0.707	4.375	0.518	-1.13
s5.1	Minimum and maximum Inventory/stock levels are defined or set	**8**	3.250	0.886	4.125	0.641	-0.88
s5.2	Stock taking/cycle counting is used to preserve reliability of stock/inventory records	**8**	3.750	0.886	4.500	0.535	-0.75
s5.3	An intelligent part numbering system is utilised	**8**	3.375	0.916	4.375	0.518	-1.00
s5.4	Usage records are employed to determine stock levels order points and order quantities	**8**	3.500	0.926	4.500	0.535	-1.00
s5.5	Maintenance, Procurement, Finance and Stores, work together to assure availability of necessary parts; elimination of obsolete parts, adjustment of stock levels	**8**	2.875	1.126	4.125	0.835	-1.25
s6.1	The system of work prioritisation effectively distinguish between legitimate rush jobs and those which can be planned	**8**	2.675	1.188	4.000	0.756	-1.33

			Perception		Expectation		
		Valid N	**Mean-(P)**	**STDev**	**Mean-(E)**	**STDev**	**Gap**
s6.2	Scheduled jobs start and completion dates, resource allocation and duration are published, distributed and communicated	**8**	3.375	0.744	4.750	0.463	-1.38
s6.3	Schedule compliance substantiated by KPI report is high	**8**	3.375	0.916	4.250	0.707	-0.88
s6.4	Planned and scheduled work is completed on time and substantiated by KPI report	**8**	3.000	0.756	4.250	0.463	-1.25
s6.5	Procedure for requesting, coordinating and controlling support services such as scaffolding; HP cleaning; rigging; cranes and workshops is effective	**8**	2.750	1.165	3.875	0.835	-1.13
		8	**3.213**	**1.012**	**4.281**	**0.651**	**-1.069**

APPENDIX U: O&U STANDARD DEVIATIONS, MEANS AND GAP FOR MMS

			Perception		Expectation		
		Valid N	**Mean-(P)**	**STDev-(P)**	**Mean-(E)**	**STDev-(E)**	**Gap**
			GAP = MEAN (E) – MEAN (P)				
s1.1	Decisions can be made and carried out at the lowest appropriate level	**10**	2.200	1.033	3.700	0.675	-1.50
s1.2	Supervisors are not so overloaded with administrative or other duties that performance of their direct supervisory duties is hampered	**10**	2.800	1.135	4.100	0.876	-1.30
s1.3	There are sufficient cross trained artisans, technicians and engineers to provide quality maintenance management service	**10**	2.900	1.197	4.200	0.632	-1.30
s1.4	Communication channels and procedures are designed for clear and quick transmission of information	**10**	3.500	1.354	4.400	0.699	-0.90
s1.5	Relationships with staff departments such as Procurement, stores, finance and others are clearly defined	**10**	3.200	1.033	4.500	0.527	-1.30
s2.1	The MMS is computerised	**10**	3.400	1.350	4.200	0.789	-0.80
s2.2	The right maintenance information is available to all levels of the organisation	**10**	3.800	0.789	4.600	0.516	-0.80
s2.3	Information is complete and reliable	**10**	3.500	1.080	4.500	0.707	-1.00
s2.4	Monthly maintenance cost reports are compiled and readily available	**10**	3.100	0.994	4.200	0.789	-1.10
s2.5	Information, data and history is accessible, retrievable and user friendly	**10**	3.500	1.080	4.600	0.516	-1.10
s3.1	Weekly and monthly look ahead plans are compiled, approved and communicated	**10**	3.800	0.919	4.400	0.699	-0.60
s3.2	Policy specifies how detailed planning of selected maintenance work is done and a target has be established	**10**	3.500	1.179	4.400	0.843	-0.90
s3.3	The concept of maintenance planning is fully accepted by maintenance supervisors	**10**	3.400	0.966	4.300	0.675	-0.90
s3.4	Planning procedures are well documented	**10**	3.500	1.179	4.300	0.675	-0.80
s3.5	All shutdown work is pre-planned	**10**	3.800	0.919	4.400	0.699	-0.60
s3.6	Short and long term outage plans are compiled, approved and communicated	**10**	3.900	0.738	4.700	0.483	-0.80

			Perception		Expectation		
		Valid N	Mean-(P)	STDev-(P)	Mean-(E)	STDev-(E)	Gap
			GAP = MEAN (E) – MEAN (P)				
s4.1	Weekly maintenance Key Performance indicators (KPIs) are compiled, issued and communicated	**10**	3.300	1.337	4.300	0.823	-1.00
s4.2	Monthly maintenance KPIs are compiled, issued and communicated	**10**	3.100	1.197	4.300	0.823	-1.20
s4.3	Visual planning boards are updated weekly	**10**	3.400	1.265	4.300	0.675	-0.90
s4.4	KPI trends are discussed bi-monthly, corrective and preventive measures devised and taken	**10**	3.200	1.317	4.600	0.516	-1.40
s4.5	Capacity plans are compiled and issued weekly	**10**	3.400	1.506	4.200	0.632	-0.80
s4.6	Maintenance KPIs add value to improvement of MMS	**10**	3.700	1.252	4.100	0.568	-0.40
s5.1	Minimum and maximum Inventory/stock levels are defined or set	**10**	3.600	0.843	4.100	0.738	-0.50
s5.2	Stock taking/cycle counting is used to preserve reliability of stock/inventory records	**10**	3.400	1.075	4.300	0.438	-0.90
s5.3	An intelligent part numbering system is utilised	**10**	3.300	0.675	4.100	0.738	-0.80
s5.4	Usage records are employed to determine stock levels order points and order quantities	**10**	3.500	0.527	4.200	0.789	-0.70
s5.5	Maintenance, Procurement, Finance and Stores, work together to assure availability of necessary parts; elimination of obsolete parts, adjustment of stock levels	**10**	3.300	0.675	4.100	0.738	-0.80
s6.1	The system of work prioritisation effectively distinguish between legitimate rush jobs and those which can be planned	**10**	3.200	0.789	4.000	0.471	-0.80
s6.2	Scheduled jobs start and completion dates, resource allocation and duration are published, distributed and communicated	**10**	3.300	0.989	4.200	0.632	-0.90
s6.3	Schedule compliance substantiated by KPI report is high	**10**	3.300	0.989	4.400	0.516	-1.10
s6.4	Planned and scheduled work is completed on time and substantiated by KPI report	**10**	2.900	1.101	4.400	0.516	-1.50
s6.5	Procedure for requesting, coordinating and controlling support services such as scaffolding; HP cleaning; rigging; cranes and workshops is effective	**10**	3.000	1.054	4.400	0.516	-1.40
	MMSI	**10**	**3.334**	**1.048**	**4.297**	**0.654**	**-0.963**

APPENDIX V: COMBINED AREAS STANDARD DEVIATIONS, MEANS AND GAP FOR MMS

			Perception		Expectation		
		Valid N	Mean-(P)	STDev-(P)	Mean-(E)	STDev-(E)	Gap
		GAP = MEAN (E) – MEAN (P)					
s1.1	Decisions can be made and carried out at the lowest appropriate level	**56**	2.696	1.043	3.839	0.826	-1.14
s1.2	Supervisors are not so overloaded with administrative or other duties that performance of their direct supervisory duties is hampered	**56**	2.679	1.081	3.982	0.884	-1.30
s1.3	There are sufficient cross trained artisans, technicians and engineers to provide quality maintenance management service	**56**	2.696	1.094	3.946	0.840	-1.25
s1.4	Communication channels and procedures are designed for clear and quick transmission of information	**56**	3.321	0.976	4.214	0.780	-0.89
s1.5	Relationships with staff departments such as Procurement, stores, finance and others are clearly defined	**56**	2.857	0.962	3.982	0.904	-1.13
s2.1	The MMS is computerised	**56**	3.750	1.031	4.357	0.749	-0.61
s2.2	The right maintenance information is available to all levels of the organisation	**56**	3.000	1.027	4.250	0.694	-1.25
s2.3	Information is complete and reliable	**56**	2.982	0.981	4.125	0.810	-1.14
s2.4	Monthly maintenance cost reports are compiled and readily available	**56**	3.286	0.889	4.143	0.796	-0.86
s2.5	Information, data and history is accessible, retrievable and user friendly	**56**	3.321	0.936	4.089	0.940	-0.77
s3.1	Weekly and monthly look ahead plans are compiled, approved and communicated	**56**	3.625	0.843	4.232	0.786	-0.61
s3.2	Policy specifies how detailed planning of selected maintenance work is done and a target has be established	**56**	3.571	1.024	4.179	0.876	-0.61
s3.3	The concept of maintenance planning is fully accepted by maintenance supervisors	**56**	3.321	0.897	4.089	0.769	-0.77
s3.4	Planning procedures are well documented	**56**	3.554	0.952	4.125	0.854	-0.57
s3.5	All shutdown work is pre-planned	**56**	3.750	1.049	4.357	0.749	-0.61
s3.6	Short and long term outage plans are compiled, approved and communicated	**56**	3.875	0.833	4.464	0.713	-0.59

			Perception		Expectation		
		Valid N	Mean-(P)	STDev-(P)	Mean-(E)	STDev-(E)	Gap
		GAP = MEAN (E) – MEAN (P)					
s4.1	Weekly maintenance Key Performance indicators (KPIs) are compiled, issued and communicated	**56**	3.357	0.999	4.107	1.021	-0.75
s4.2	Monthly maintenance KPIs are compiled, issued and communicated	**56**	3.429	0.912	4.125	1.010	-0.70
s4.3	Visual planning boards are updated weekly	**56**	3.054	1.017	3.929	1.076	-0.88
s4.4	KPI trends are discussed bi-monthly, corrective and preventive measures devised and taken	**56**	3.339	0.920	4.089	0.959	-0.75
s4.5	Capacity plans are compiled and issued weekly	**56**	3.393	1.039	4.125	0.896	-0.73
s4.6	Maintenance KPIs add value to improvement of MMS	**56**	3.286	0.986	3.982	0.944	-0.70
s5.1	Minimum and maximum Inventory/stock levels are defined or set	**56**	3.554	0.913	4.196	0.699	-0.64
s5.2	Stock taking/cycle counting is used to preserve reliability of stock/inventory records	**56**	3.661	0.900	4.375	0.648	-0.71
s5.3	An intelligent part numbering system is utilised	**56**	3.404	0.852	4.107	0.846	-0.70
s5.4	Usage records are employed to determine stock levels order points and order quantities	**56**	3.304	0.829	4.125	0.854	-0.82
s5.5	Maintenance, Procurement, Finance and Stores, work together to assure availability of necessary parts; elimination of obsolete parts, adjustment of stock levels	**56**	3.054	0.999	3.946	0.883	-0.89
s6.1	The system of work prioritisation effectively distinguish between legitimate rush jobs and those which can be planned	**56**	3.054	1.069	3.857	0.883	-0.80
s6.2	Scheduled jobs start and completion dates, resource allocation and duration are published, distributed and communicated	**56**	3.321	0.917	4.143	0.883	-0.82
s6.3	Schedule compliance substantiated by KPI report is high	**56**	3.125	0.833	4.000	0.786	-0.88
s6.4	Planned and scheduled work is completed on time and substantiated by KPI report	**56**	2.946	0.916	4.054	0.724	-1.11
s6.5	Procedure for requesting, coordinating and controlling support services such as scaffolding; HP cleaning; rigging; cranes and workshops is effective	**56**	2.911	1.100	4.089	0.837	-1.18
	MMSI	**56**	**3.265**	**0.963**	**4.113**	**0.841**	**-0.848**

			Perception		Expectation		
		Valid N	Mean-(P)	STDev-(P)	Mean-(E)	STDev-(E)	Gap
		GAP = MEAN (E) – MEAN (P)					
	Pearson product moment Correlation [r]		0.80				
	Coefficient of Determinant (R Squared)		0.64	64%			